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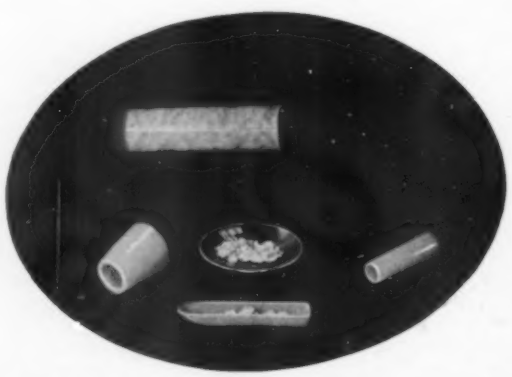

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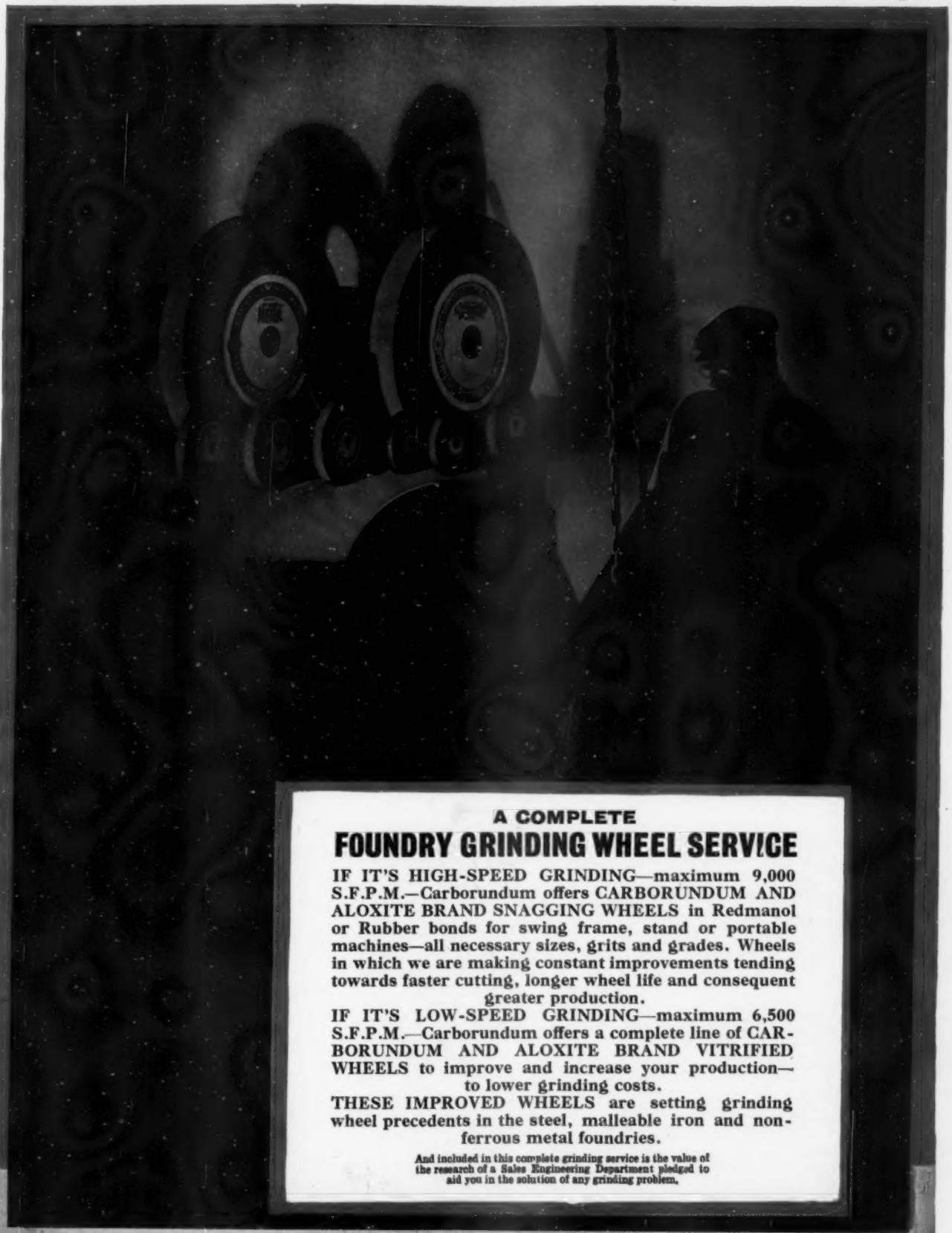

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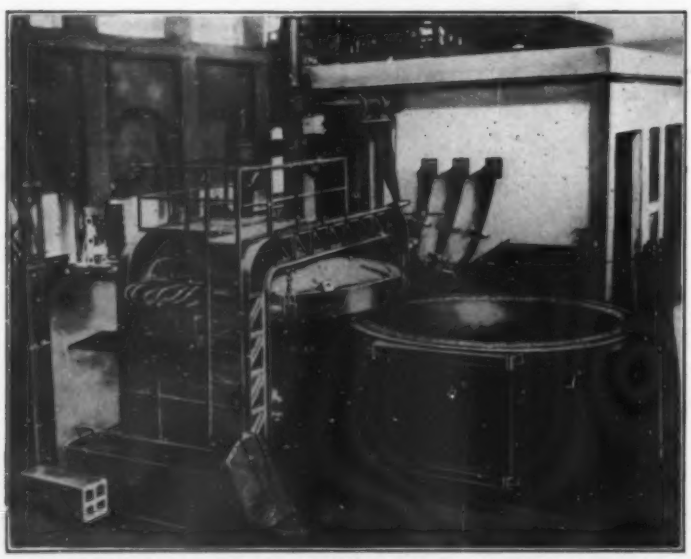

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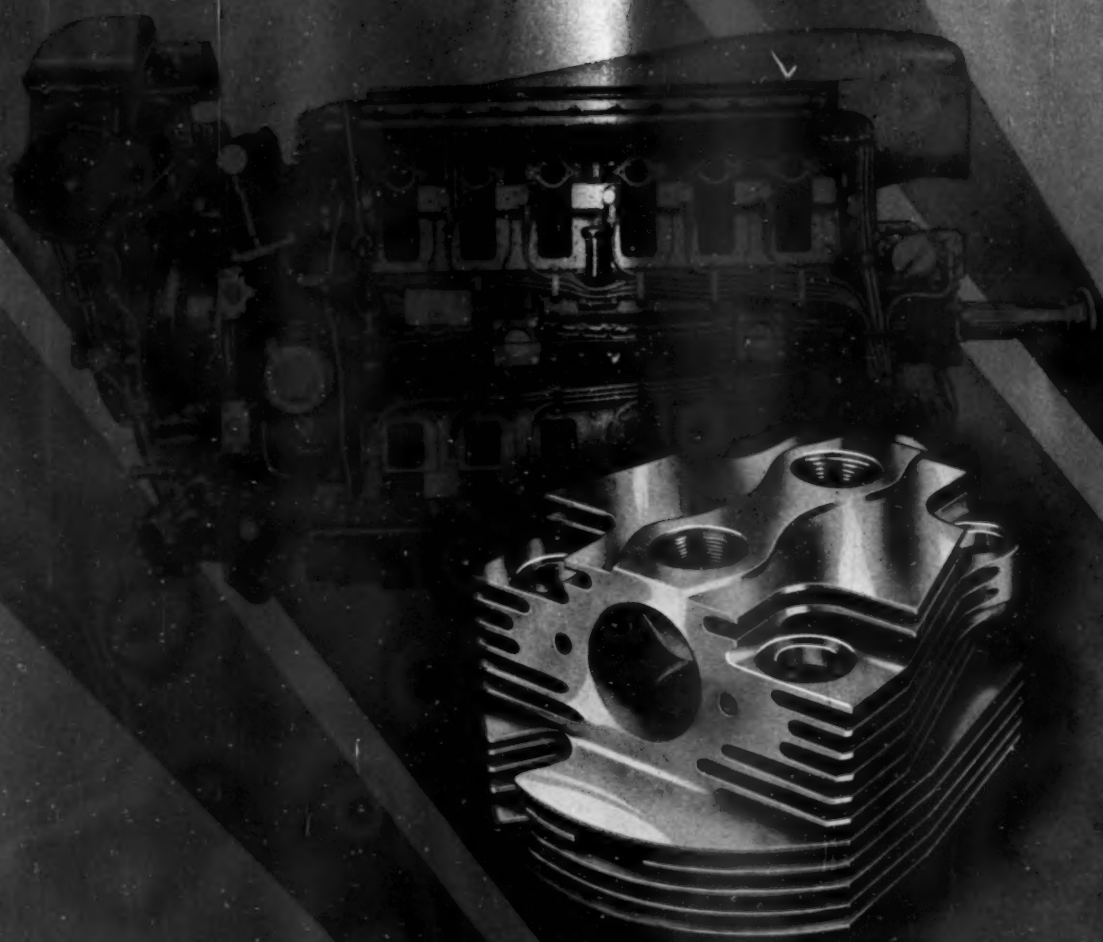

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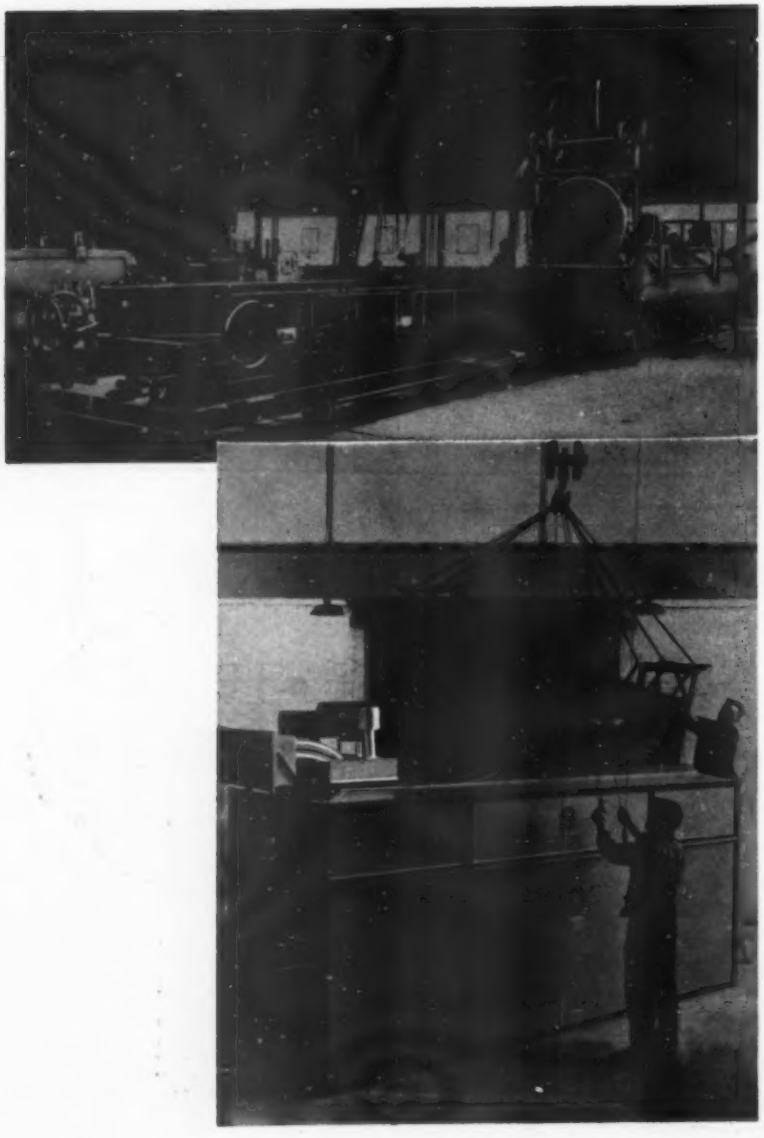

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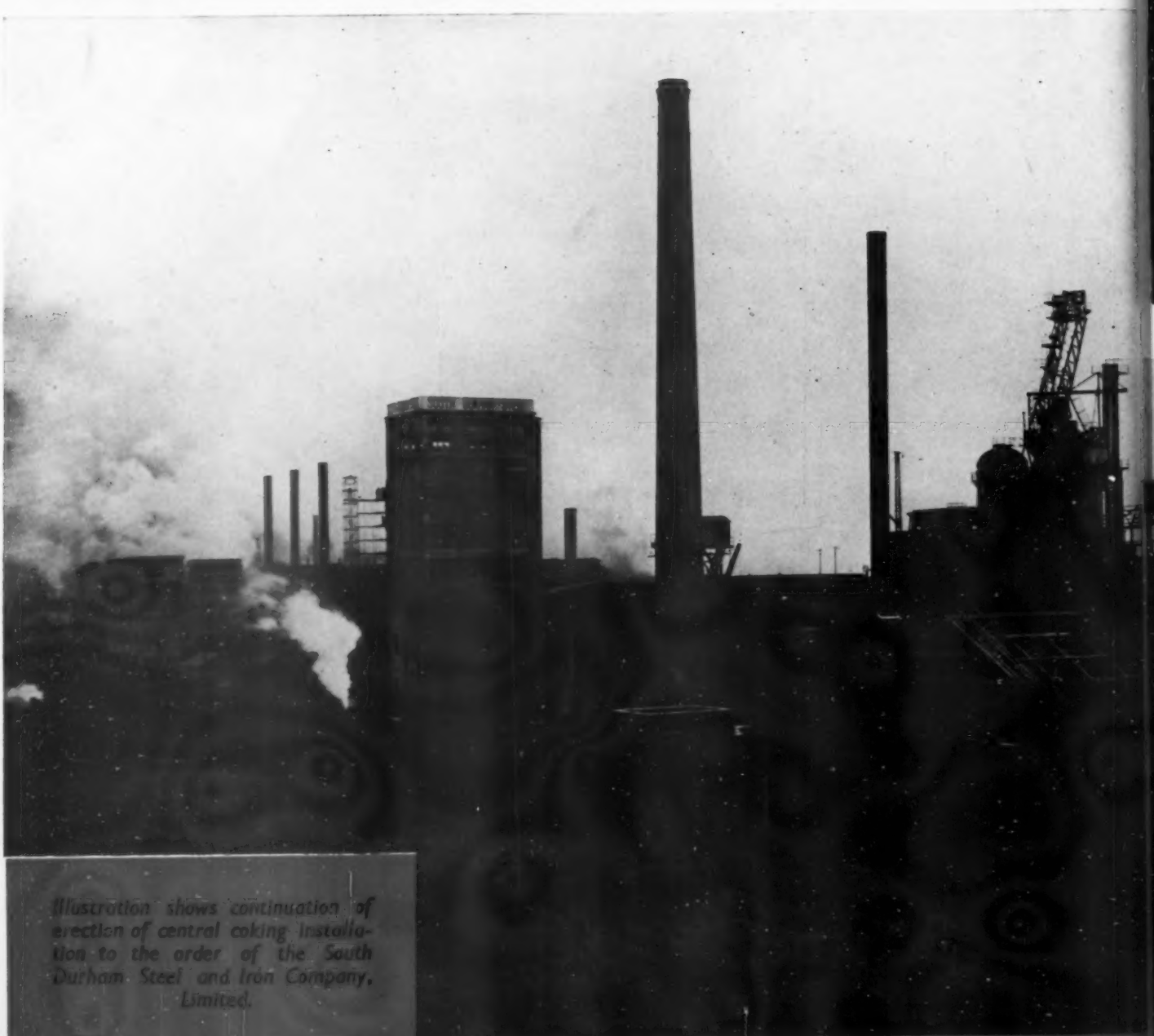

Illustration shows continuation of erection of central coking installation to the order of the South Durham Steel and Iron Company, Limited.

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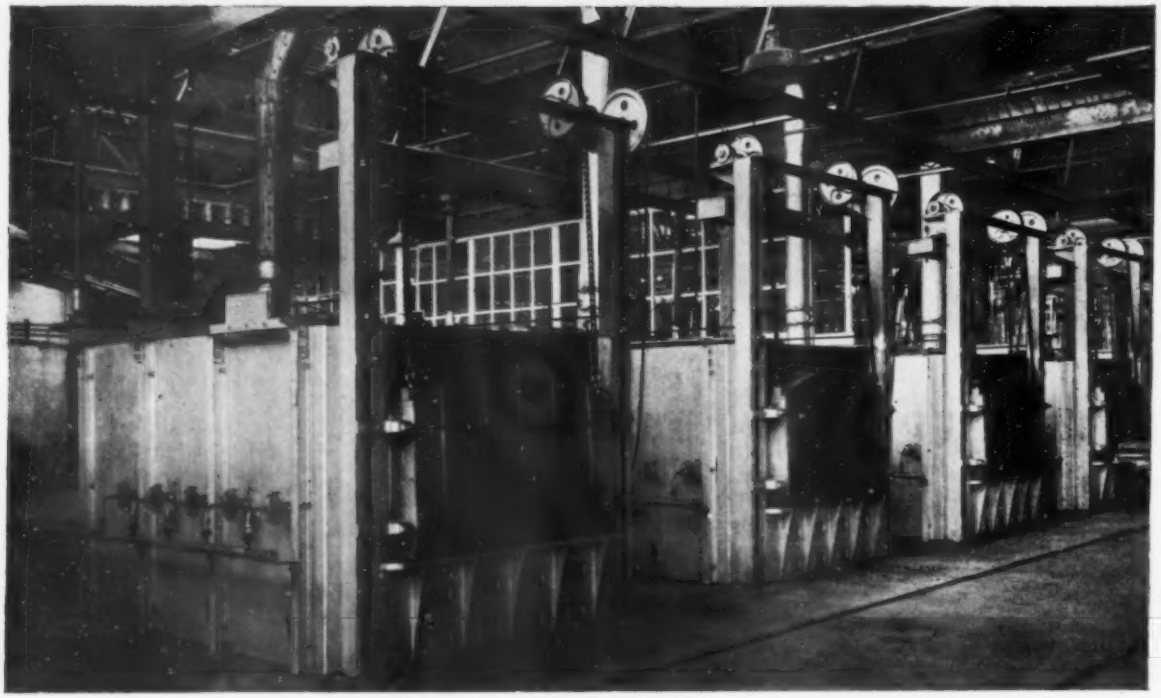

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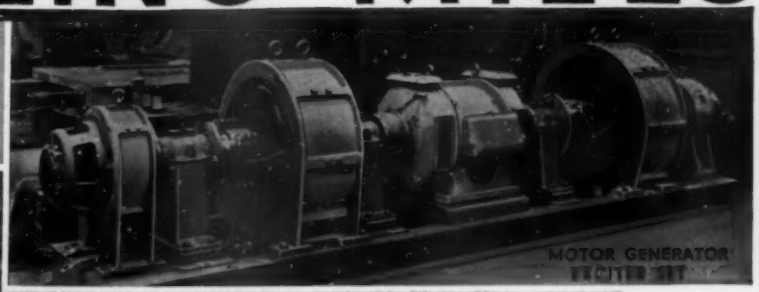

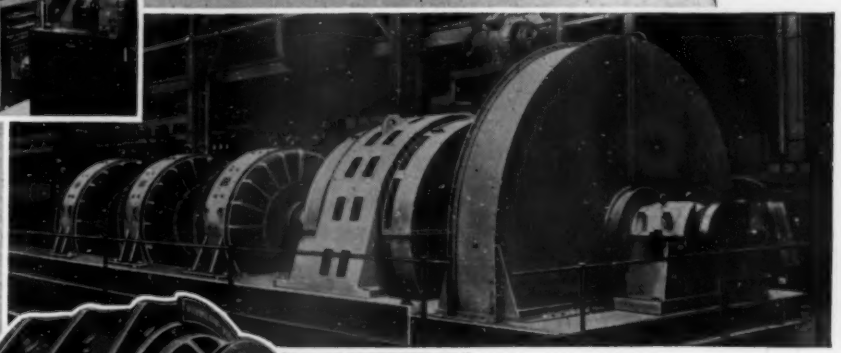

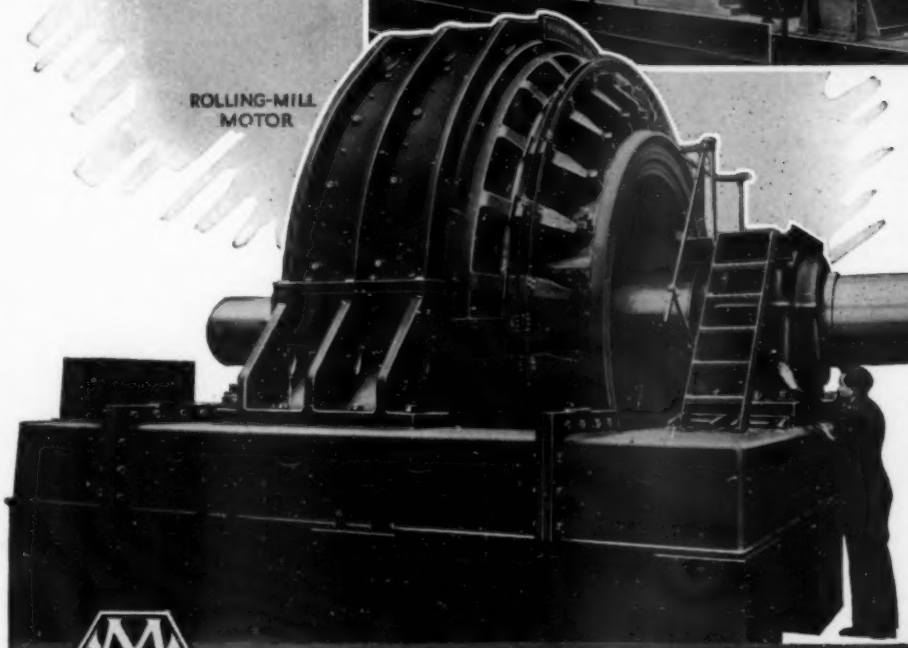

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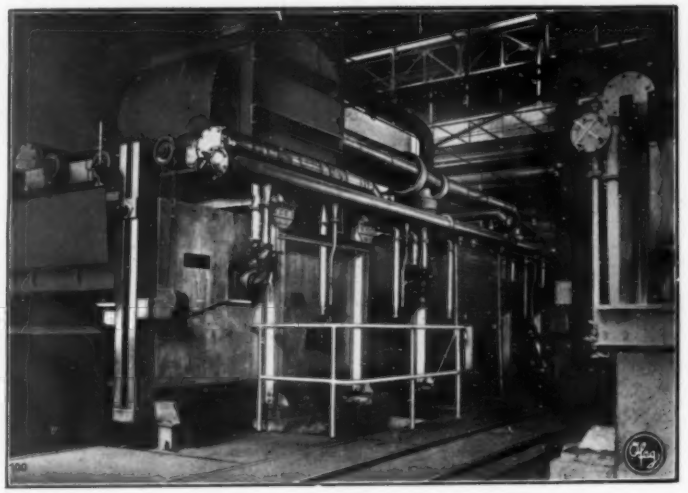

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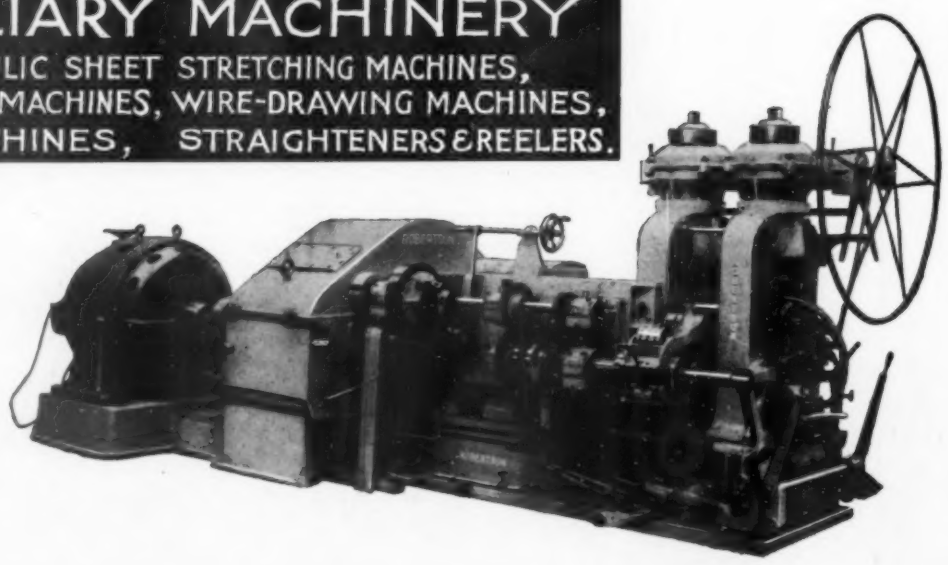

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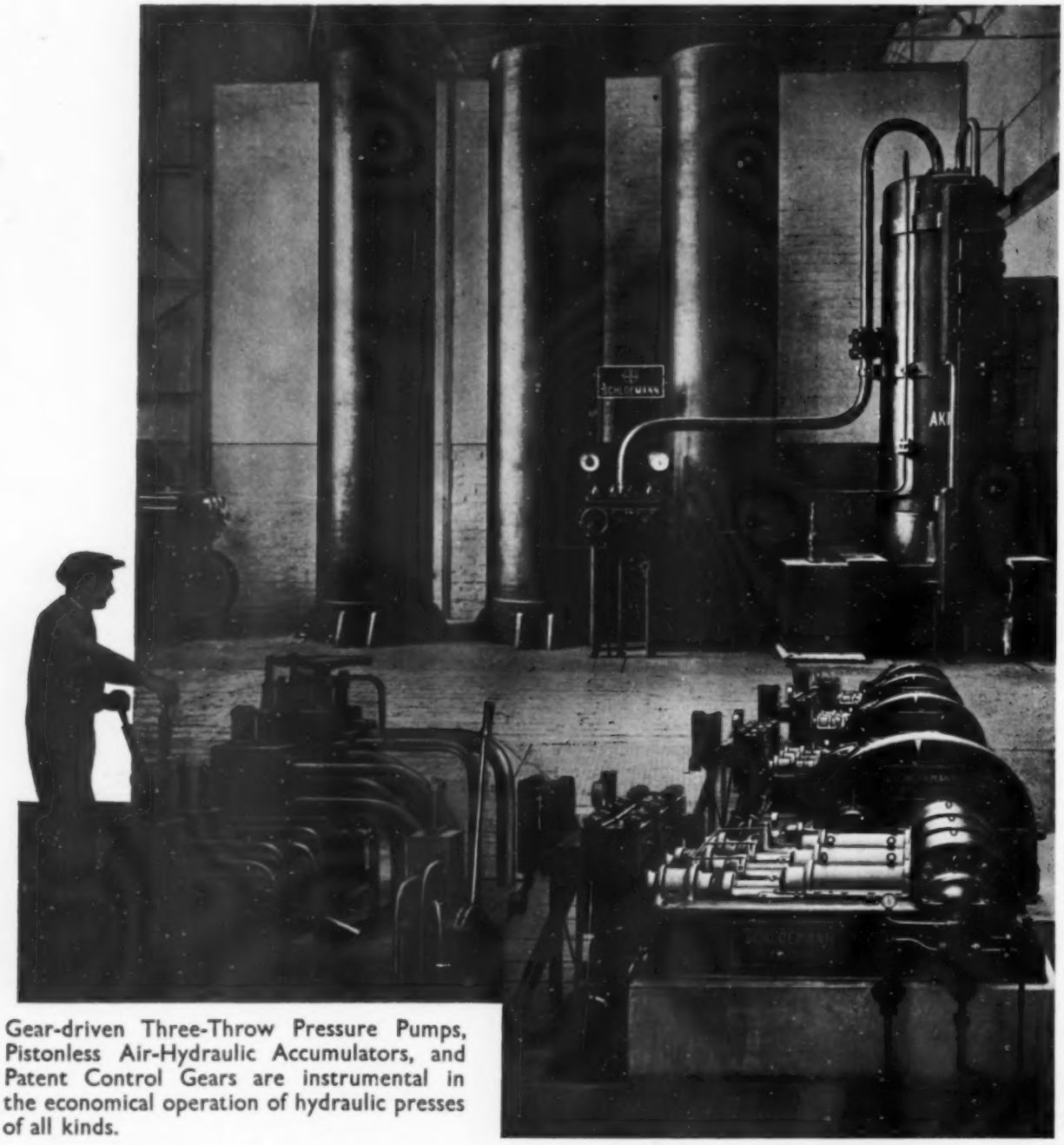

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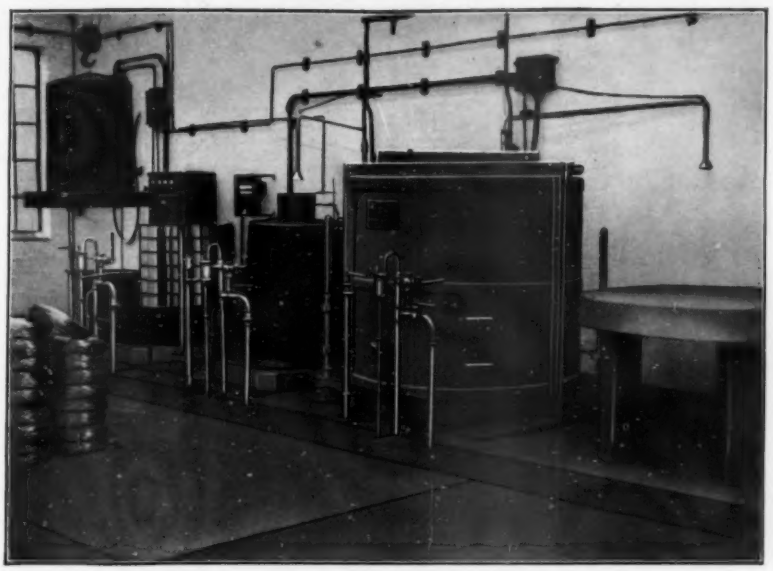

By courtesy of Messrs. Connollys (Blackley), Ltd.

50 kW. "EFCO" Copper Wire Annealing Furnace.

Electric Bright Annealing Furnace

THROUGH the kindness of Messrs. Connollys (Blackley), Ltd., we are able to publish these particulars and photograph of an interesting dry bright annealing furnace which has recently been put into operation at the Blackley Works.

The actual heating "bell" (seen in the centre of the picture), is rated at 50 kW. and is connected to the 3-phase, 400 volt supply. The process consists of annealing copper wire, in all guages down to 0.002 in. diameter, and the finished product is perfectly dry and bright, a condition which is an essential feature in modern wire supplies. The photograph has been taken so as to show the different stages in the process. In the left foreground are coils of bright wire, as they come from early stages of drawing. In the left background wire is seen wound on spools, in which state it can be treated equally well. The wire, in either form, is stacked on the first charge plate, which has a waterseal around the base. The light metal hood, seen suspended from the hook of the overhead gantry, is then lowered over the charge and sealed off.

In the next stage the air in the hood is purged by passing through it gases, consisting largely of nitrogen. These are in fact the products of combustion resulting from burning producer gas in the air. The mixture is carefully purified to remove every trace of sulphur, dried and stored in a small gas holder. It is then circulated around the charge by internal fans during the whole of the annealing process, which is carried out at a temperature of 420/500°C. and lasts about three-quarters to one hour. These fans, incidentally, are driven by vertical shaft motors, each mounted in a pit under its respective charge plate. When the hood is purged to the right extent, the bell-shaped furnace is lowered over it, and annealing proceeds. The photograph shows the furnace over the first charging plate. On the second one (left centre) annealing has been completed and a water spray is cooling off the hood and charge. The third one has already been referred to.

On the extreme right is a concrete heat insulating "bottom," on which the heated bell may be rested if any one of the three hoods is not immediately ready to receive it. It would be noted that one furnace serves three charging bases, permitting continuous and efficient working.

This plant deals with about 45 tons per week of various gauges of copper wire. It replaces an old coal fired furnace of the conveyor type having water seals at either end, and the electric method has proved itself cheaper and, in every respect, superior.

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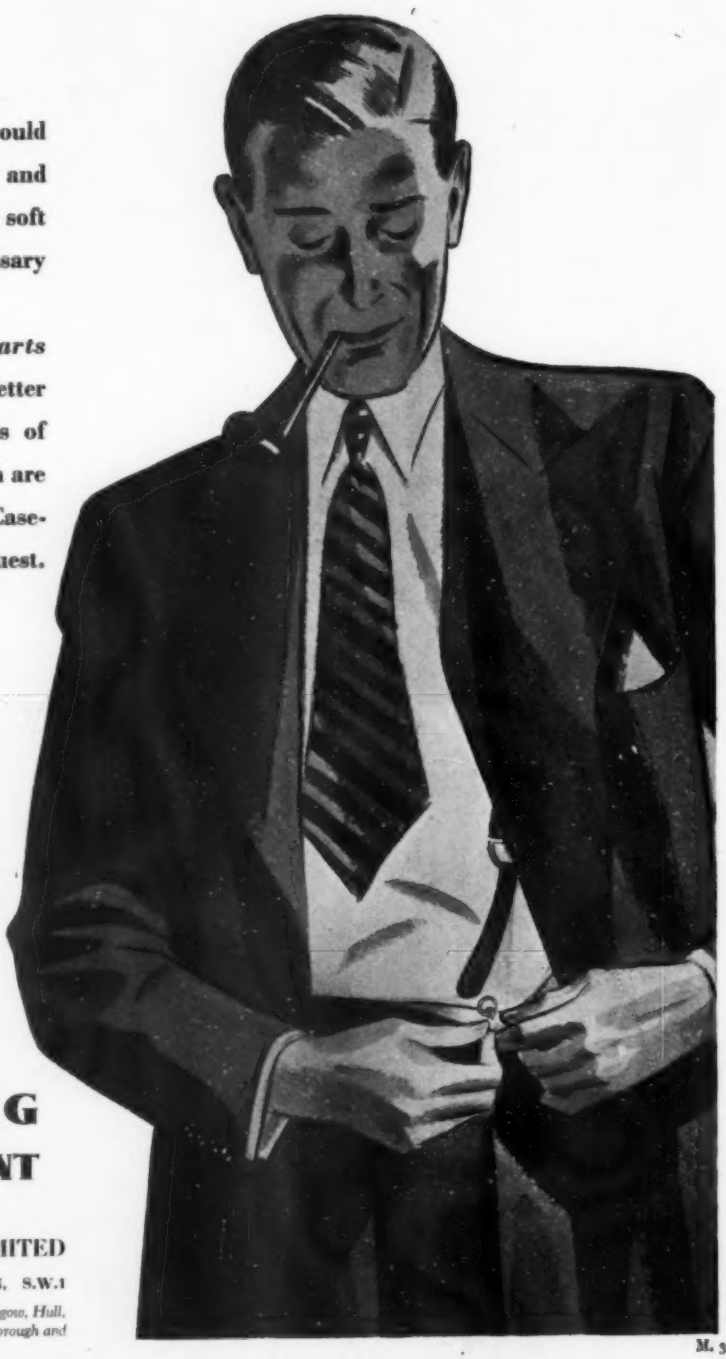
What has CASEHARDENING *to do with a bachelor's button?*



The split ring of the bachelor's button would be very expensive to make of hardened and tempered spring steel. So it is made of soft steel and casehardened to give the necessary stiffness and "springiness."

Bachelor's buttons to aero engine parts **—anything that needs casehardening is better done by the "Cassel" Cyanide Processes of Casehardening and Heat Treatment. Both are described in the books "Modern Methods of Casehardening" and "Rapideep," free on request.**

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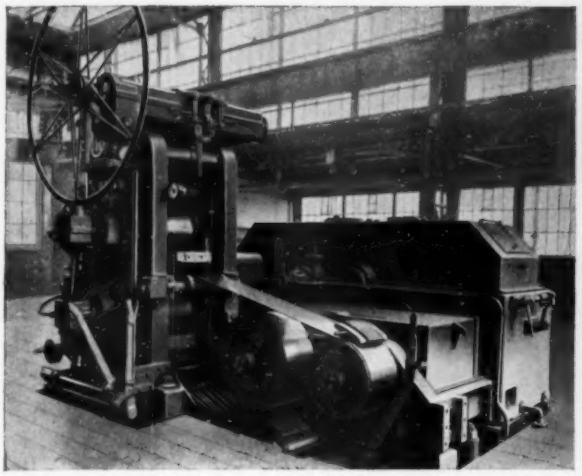
without intermediate anneal



has been obtained on this Cold-Rolling Mill when working SM quality steels. All kinds of ferrous and non-ferrous metals, especially stainless steels, may be handled as well on this mill which produces perfectly accurate strips.

Even broad Strips may be handled with the MES High Speed Cold Rolling Mill and reduced thereby to thinnest gauge with perfect accuracy.

The resulting output per hour far surpasses the customary figure.

Additional advantages :

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We solicit your enquiries.

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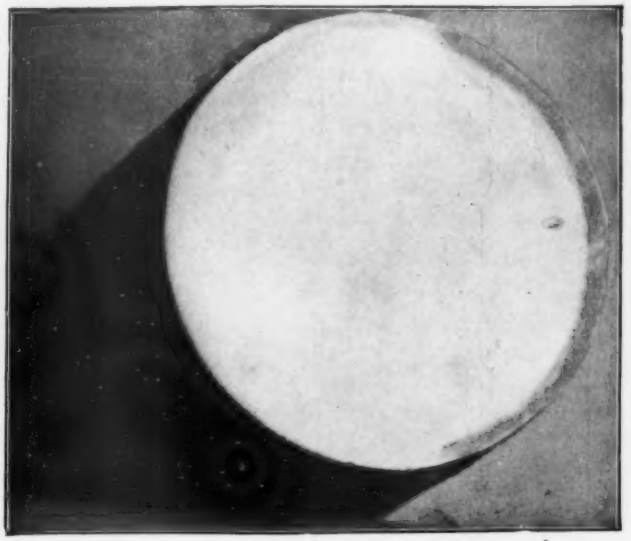

CONTROLS YOUR CASE-HARDENING

NOTE THE PART NOT TREATED IN THE ABOVE PHOTOGRAPH.

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Are you willing to try a new method of doing an old job ? Then try " Anti-Cementite " **in paste or powder form** for local case-hardening. Copper plating, claying up, or machining off, after carburising those parts required soft, are all old methods, each having disadvantages.

" Anti-Cementite " will combine the good points of the old methods, with none of their bad ones.

The limits of the Kasenit carburised sector are clearly shown in the steel bar. You will note that the rest of the circle is evenly clear of " case."

Sample on request to prove results.

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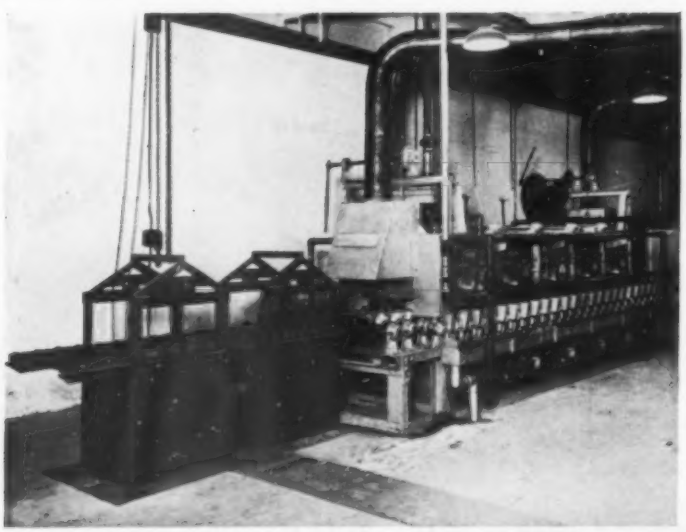

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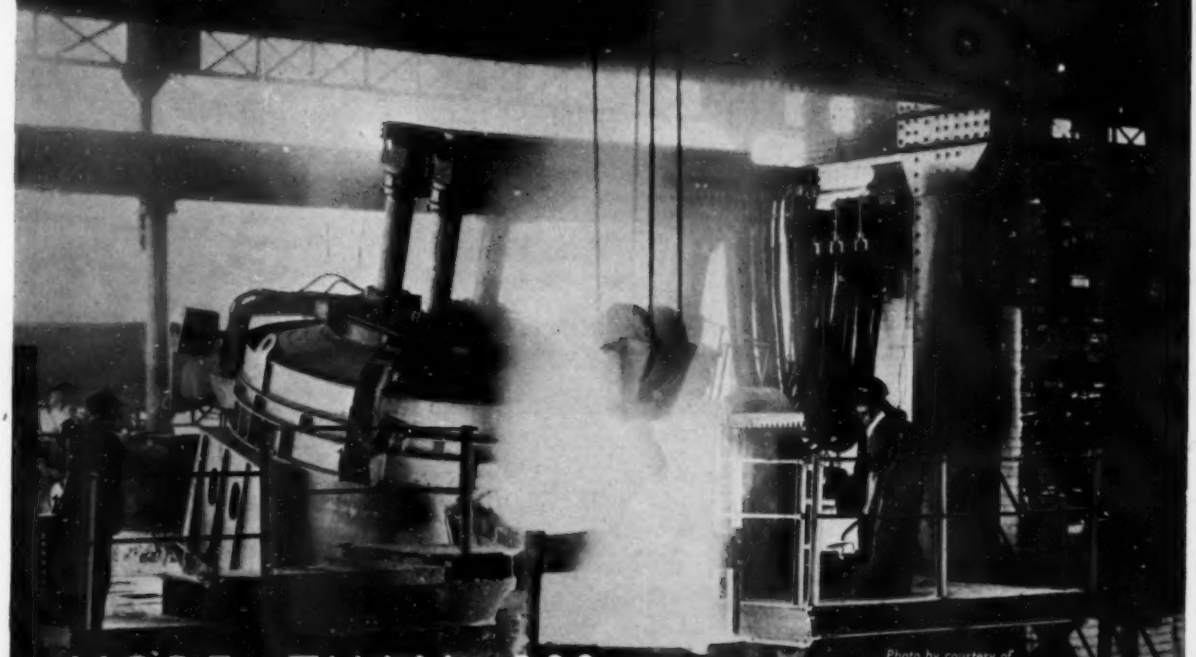

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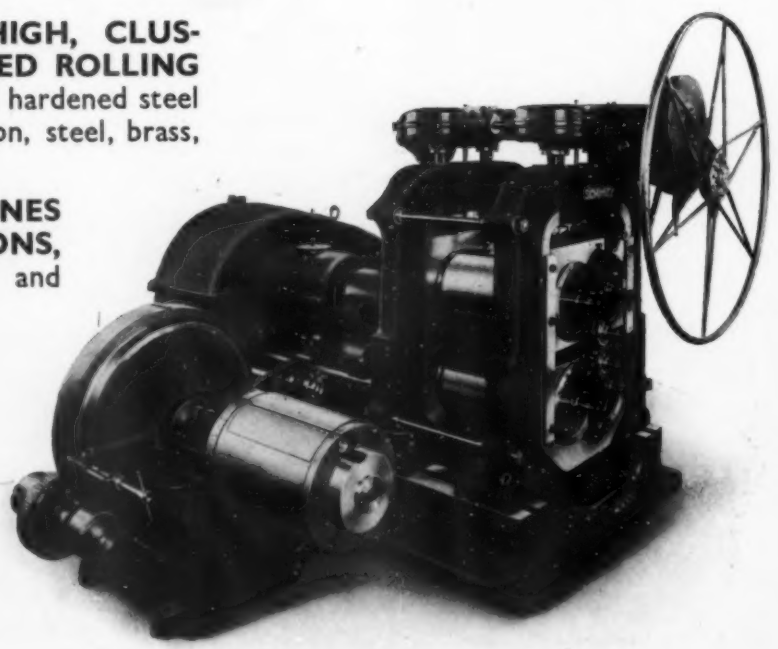

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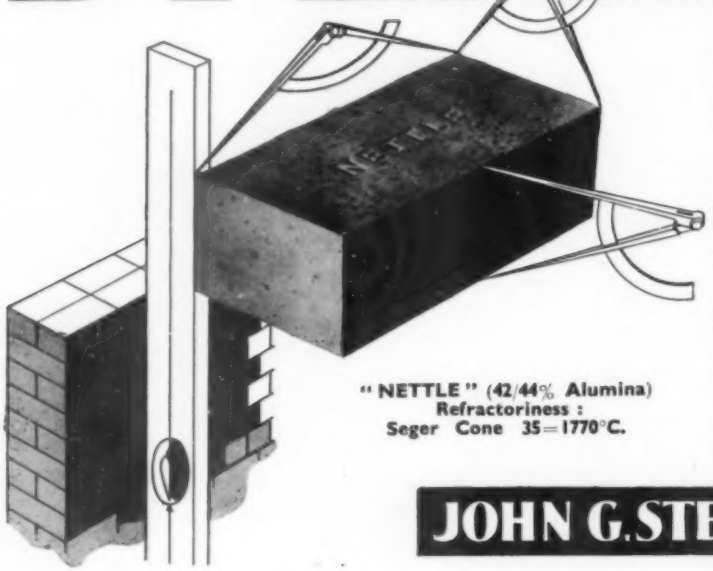

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JUNE, 1937. VOL. XVI, No. 92.

Some Electric Furnaces For Aluminium Alloys

By G. B. LAMB, B.Sc., A.C.G.I.

Electric furnaces have played no small part in the development of strong light alloys, since accurate heat-treatment is essential to bring out the best physical properties. In this article some furnaces which are being used for this purpose are discussed.

THE specific gravity of pure aluminium in the cast state is about 2·56, which is approximately one-third of that of steel: its hardness, however, is only in the region of 20 Brinell. In spite of its softness, its possibilities were realised even in the early days, and after much research, alloys have been produced with physical properties approaching those of steel with, of course, very light weight, as the majority of these alloys contain over 93% of aluminium. The properties which can be given to the various alloys, in recent years has brought a very great demand from a wide variety of engineering firms, particularly those in the automobile and aircraft industries, in which their advantages are obvious.

Without belittling the efforts of research workers who have discovered what constituents, when added to aluminium, give the best alloys, it can be said that electric furnaces have played no small part in the ultimate results obtained, as accurate heat-treatment is essential to bring out the best physical properties. An instance of the type of treatment employed in many cases, is that for forged R.R. 59 material. The treatment required is two hours at 530° C., during which time the hardening constituents go into solution—the material is then quenched in cold water. The precipitation treatment then follows for 20 hours at 170° C. with a further cold-water quench. As a result of these prolonged treatments, provided they are carried out correctly, the hardness is raised to as high as 160 Brinell, and the stress to 29 tons per sq. in.

At temperatures below 600° C., which covers the entire range of light aluminium alloy heat-treatments, transfer of heat by radiation is slow, most of the heat being transferred by connection currents. In a furnace which is used for low-temperature treatments, it is therefore essential to produce a turbulent atmosphere in order to obtain rapid heat transference from the heating elements to the charge. In electric furnaces the method of obtaining forced-air circulation is to fit one or more fans in the furnace chamber. The number of fans employed depending on the type and size of furnace. Normally speaking, the heating elements are on or near the walls of the chamber, and circulating air carries the heat from the elements to the charge and, what is more important, distributes the heat uniformly throughout the chamber, so that in addition to the rapid heating effected, very close temperature uniformity is assured.

Batch Furnaces

Due to the nature of the treatments required, continuous furnaces are not used, except for billet heating prior to forging; and frequently, except for large billets which cannot otherwise be handled easily, batch furnaces are

Fig. 1.—Box type furnaces with forced air circulation for heat-treating aluminium alloy aero engine parts.

Fig. 2.—Vertical forced-air circulation furnace for heat-treating aluminium alloys and stainless steel.

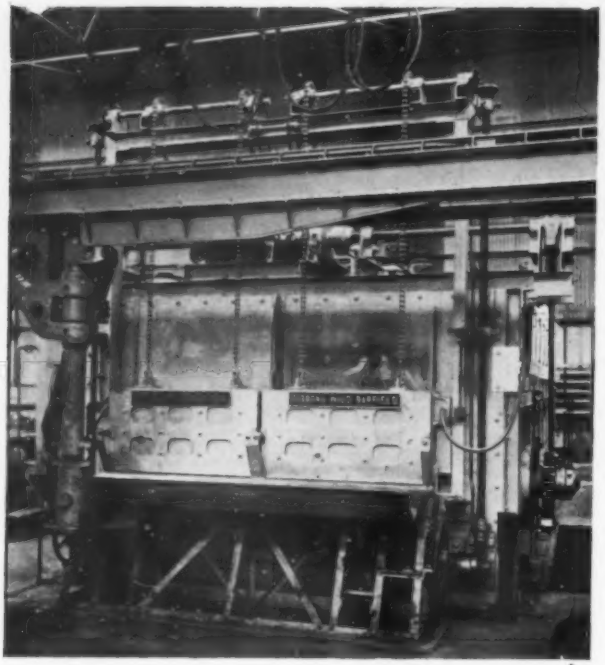


Fig. 3.—Conveyer furnace for heating aluminium alloy billets prior to forging.

used for this purpose, also. Strictly speaking, billet heating for forging is not a heat-treatment process, but it is of interest to note that electric furnaces are widely used for this purpose. Continuous furnaces for this purpose are described later.

Depending on the nature and size of the parts to be treated and on the handling facilities available, the two types used are the vertical and horizontal furnaces, the former being particularly useful for smaller articles while larger forgings can most easily be handled in the latter.

Fig. 1 shows two horizontal box-type furnaces used for heat-treatment aluminium alloy aero engine parts. Two vertical spindle motors on the top of each furnace will be noticed. The centrifugal fans in the furnaces are driven by these motors, the shaft extension and the fan being made of heat-resisting material. The fans are of the two-bladed, diamond-shaped type ; up to the present it has been found that this form is least liable to distortion, and combines effectiveness with low manufacturing costs. No definite path is provided for the air circulation, but the fans are run at the highest possible safe speed, so that the maximum turbulence is created.

In small horizontal furnaces only one fan is fitted, but with long furnaces, in order to create satisfactory circulation throughout the chamber it is essential to fit more than one fan. The volume of air circulated by a number of centrifugal fans is proportioned to the following factors : (*a*) The diameter of the fans, (*b*) the blade depth, (*c*) the speed of the fans, (*d*) the total number of fans. Consequently to produce the maximum possible turbulence the above factors should be as large as possible within certain limits. From a mechanical point of view the maximum peripheral speed at the tips of the fans is 110 ft. per sec. Direct drive by vertical squirrel-cage motors is usually employed, and the bearings must be designed with care on account of the long shaft extensions. Precautions must also be taken to prevent oil from the bearings finding its way into the chamber.

For long furnaces, or furnaces for heavy parts, a charging machine is usually used, and this may either be hand- or electrically-operated. Except where aluminium sheets have to be handled, charging machines are not very frequently employed. On account of the low specific gravity of aluminium the majority of furnaces for aluminium and its alloys are charged by hand.

A type of furnace which is widely used for aluminium alloy treatments is the vertical furnace which by virtue of its shape enables the charge to be easily handled. Charging is best carried out by some form of hoist, which may be either hand- or electrically-operated. The work to be treated is placed in a jig or basket, and can thus be easily loaded into the furnace. As quenching is nearly always necessary the quenching tank can be placed alongside the furnace, and in this way very little time is lost between the uncharging and quenching, which is an important point to ensure the best results. Fig. 2 shows a vertical furnace with quenching tank and hoist. It will be seen that both the furnace and tank are sunk into the floor to facilitate handling.

In the above-mentioned furnace a definite path is provided in which the air circulates, as this type of furnace readily lends itself to this construction. The fan of the centrifugal type is fitted at the bottom of the furnace. Round the basket containing the charge is a baffle, between which and the chamber wall are the heating elements of nickel-chromium wire wound on grooved refractory formers. The air circulates over the elements, where it is heated, and is then drawn down through the charge where the heat is retransferred to the charge. A throat is fitted below the work basket to increase the efficiency of the fan. An interesting feature employed in the majority of these vertical furnaces with forced-air circulation is the " Progress Recorder," which combines the function of both automatically controlling the furnace temperature and informing the operator when the charge is up to temperature. There are two thermo-couples connected alternately to the recorder, one thermo-couple placed above the charge, the other below. Consequently, when the charge is up to temperature the two records coincide. If a soaking period is necessary the exact time is given, and in addition there is a permanent record of every heat-treatment carried out, so that if subsequent defects are discovered in a batch of work it is possible to check quite easily as to whether the treatment accorded to it was correct or not. The floor mounting Charge Progress Recorder can be seen alongside the switchgear panel in the illustration.

As mentioned above, the quenching after heating forms an important part of the heat-treatment. For instance, aluminium alloy " Y " requires to be quenched in boiling water. This material, which was developed by the National Physical Laboratories in research for a suitable alloy for pistons, has a high thermal conductivity strength and a low co-efficient of friction, at the high temperatures which exist in the cylinder of an internal-combustion engine. To bring out the required properties the full heat-treatment is as follows. The cast material is first heated at 530° C. for two to four hours, depending on the thickness and size of the castings : this is followed by a quench in boiling water. There is further treatment at 200° C. for two to four hours, after which the supply to the furnace is switched off and the charge allowed to cool in the furnace for at least two or three hours. An electrically-heated quenching tank is frequently employed, the heating elements being of the immersion type as used in domestic water-heating installations. Several heaters are used, and switches are provided to enable series parallel operation. The latter connection for rapid heating up from cold, and the former for maintaining the temperature. Temperature control is by a thermostat, and the tank is well lagged to reduce the heat losses. Once the water has been heated to the required temperature very little power is needed to maintain it, as the quenching hot charges keep the water boiling. The tank must be considerably larger than the work basket holding the charge, both to ensure a rapid and satisfactory quench and to avoid any danger of the water spilling over the side of the tank due to rapid boiling on insertion of the hot charge.

Salt Baths

Apart from forced-air circulation furnaces, electrically heated salt baths are used in some instances. They have the advantage of slightly more rapid heating than fan furnaces, although this is not of particular importance for aluminium alloys, as the majority of the treatments require long soaking periods. Salt baths have many disadvantages compared to forced-air circulation furnaces. The temperature uniformity is not so good, and there is the continuous replacement of salt. The operating conditions are inferior and, unless care is taken, the danger is great. On the other hand, forced-air circulation furnaces are clean and safe to operate under normal conditions. Temperature control and unformity are very close and the thermal efficiency is relatively high.

Conveyer and Continuous Furnaces

While such accurate temperature control is not as essential for billet heating as for aluminium-alloy heat-treatment, the many advantages of electric heat have led to the wide-spread use of electric furnaces for aluminium-alloy billet heating. Various types of furnaces are employed for the purposes amongst which are straightforward horizontal box-type furnaces as previously described, continuous-roller hearth furnaces, conveyer furnaces, pusher furnaces, etc. Fig. 3 shows a chain conveyer furnace for aluminium-alloy billet heating. The rating of this, 180 kW. divided into two separately-controlled zones, a short zone at the entry end, and a longer one towards the exit, where the billets are soaking to ensure that they are up to the forging temperature. The handling of the billets in the furnace is done throughout by electric motors operated by push button. The billet is rolled out to the loading cradle at floor level; the door opens, and the billet is raised to the conveyer level at the same time, and then tipped on the conveyer. The billet passes slowly through the furnace and on reaching the exit end it rolls on to a cradle inside the furnace chamber; this cuts out the conveyer driving motor to prevent any more billets being discharged. When the operator is ready to remove the billet, on pressing the motor-control button the exit door is raised, the cradle is tipped up, and the billet rolls on to a platform where it is removed to the forging press.

This furnace will handle two rows of 16-in. dia. billets weight 7 cwt. each, or four rows of shorter billets, and is capable of an output of two to two and a-half per hour. Three centrifugal fans are fitted in the roof to ensure uniform and rapid heating. The length of the furnaces, excluding charge entry and exit vestibule is 21 ft. 8 in. with a width of 7 ft. 6 in. The conveyer is totally enclosed in the heat insulation and heating elements are fitted in the roof and below the forward-travelling portion of the conveyer.

Fig. 4 shows a continucus-roller hearth billet-heating furnace. Charge and discharge roller extensions are provided at each end, these rollers are hand operated, while the rollers in the furnace are driven continuously by an electric motor. Three separately controlled zones are fitted with separate temperature recorders on each zone. This furnace is not equipped with fans, because of the height of the furnace which has to accommodate large billets. Owing to this height the turbulence caused by the fans would not be local as in the conveyer furnace described, and consequently there would be danger of the heated billets at the exit losing some of their heat to the cold billet just inserted.

Oil- and other fuel-fired furnaces are in use for aluminium-alloy heat-treatments, but although generally they are cheaper in first cost, it is claimed that the many operating advantages and low running costs of electric furnaces outweigh, in the long run, their slightly higher initial cost.

Fig. 4.—Roller hearth furnace for heating aluminium alloy billets.

Many of the details mentioned are the subject matter of patents. Acknowledgement is due to Wild-Barfield Electric Furnaces Ltd., and G. W. B. Electric Furnaces Ltd., for their permission to publish the illustrations appearing with this article.

Journal of the Institute of Metals; Volume LIX (Proceedings). No. 2, 1936

THOUGH the Institute of Metals has held meetings in many European countries, it was not until last autumn that this society of engineers and metallurgists first sampled French hospitality. From the record of the Institute's "Paris Autumn Meeting," contained in this journal, it would seem that the meeting was highly successful—technically as well as socially.

The Editor deals but briefly with the dances, receptions and excursions that form a normal part of such a gathering in Paris, and makes up for his reticence in this direction by printing in full the 16 papers that were read at the business sessions—with the relative discussion and communications noted verbatim,—but also the very informative Autumn Lecture by Professor P. A. Chevenard on "The Scientific Organisation of Works." Hitherto available only in French, the lecture is sure of a welcome in its English form by all who have anything to do with factory management or control.

The papers reproduced in the present volume cover such varied fields as soft soldering, production of aluminium reflectors, platinum group metals, forgeability of light alloys, and the creep of tin. The authors include distinguished French, German, Russian and Swiss investigators, as well as many British workers. The general impression obtained by a careful perusal of this volume is that the Institute responsible for its publication is singularly fortunate in possessing amongst its members so many famous metallurgists and engineers—men who are willing to come from all parts of the world (14 nations were represented at the Paris Conference) to throw their knowledge into a common pool, whence it crystallises out in so useful a shape as the volume before us.

Edited by G. SHAW SCOTT, M.Sc., F.C.I.S.; published by the Institute of Metals, 36, Victoria Street, Westminster, S.W. 1. Price, 31/6.

Corrosion Wear in Ball and Roller Bearings

BALL and roller bearings will show very slight wear and give little trouble in service, even though overloaded, inadequately lubricated, or operated at excess shaft speeds, yet bearings which appear to have less onerous duties may equally suffer serious damage by indentation. In all cases of indentation, the fact that the bearings are at rest or have periods of rest, and also that vibration is present should be noted. In discussing this question, J. O. Almen* considered the effects of vibration during shipment, oxidation, and lubrication ; quoting a number of informative experiments and concluding that the indentations that are observed result from a form of wear which is dependent upon or aggravated by the presence of oxygen. The situation cannot become serious if air is excluded from the region of contact between the races and balls or rollers. Oxidation wear can be greatly reduced, but cannot be eliminated by the use of low-viscosity lubricants. Use of these lubricants for many installations of ball and roller bearings is impractical, due to inadequate oil seals.

The author states that bearings need not be heavily loaded to produce indentations, although in general, the greater load the greater the damage ; but with certain experimental conditions, decreasing damage with increasing load could be shown. A characteristic of indented bearings is a rust accumulation in the region of the damaged area, although this rust is not often observed in practice because the rotation of the bearing after a period of vibration soon mixes the oil or grease used for lubrication with the rust.

Indentations in the bearing races opposite each of the balls or rollers on the loaded side of the bearings have the appearance of having been caused by extremely high pressures, and are erroneously said to be " Brinelled."

It is pointed out that many antifriction bearings that are normally at rest and used mainly to avoid static friction, or which move through very small angles, can also suffer this form of damage. Such parts include automobile stub axle pins, other steering gear parts, spring shackles, and valve rocker arms. In aircraft, bearings of variable pitch propellers have suffered extremely, the movement of the blade in adjusting the airscrew pitch being relatively small, but the vibration of the airscrew and of the engine unit causing the trouble. In a similar way, the inner and outer races of an aircraft engine valve-rocker bearing showed considerable indentations, these being formed during periods of rest between valve opening and closing, when the bearing carried negligible load, but was vibrated severely by the engine. This trouble was practically eliminated by replacing grease lubrication by oil.

Mention is made of experiments by G. A. Tomlinson on the effect of the friction of small balls on steel plates, finding that these produced oxidation similar to that which occurs in ball and roller bearings. He concluded that the damage was caused by tangentially acting cohesive forces lifting out metal particles which were so small that they oxidised immediately. In support of that theory of molecular cohesion, a simple experiment was quoted.

The experiments of Dr. M. Fink are also quoted, and show that oxidation is not a secondary effect, but an essential component of wear. In regard to this " Brinelling " of ball and roller bearing races, Fink's theory of wear oxidation appears most nearly applicable, but that does not mean that the wear of other machine parts could necessarily be explained by that theory. For instance, the wear destruction of gear teeth by scoring in service seems to agree not with the Fink theory, but with the weld theory of Tomlinson.

Various lubrication tests, including observation of wear of metals sealed in vacuum, indicates that low viscosity lubricants should be used whenever possible for bearings subject to oxidation. Heavy greases are apparently pushed aside by the rollers or balls, and air is admitted to the area of contact with resulting rapid oxidation. Lighter lubricants are held to the balls and races, and provide the contact area with a certain degree of protection against air, although it must be admitted that some proportion of oxygen will be contained in the oil itself.

Another point of interest is that severe corrosion is frequently found on machine parts that are attached to one another in a manner designed to prevent relative movement, such as press-fitted wheels and axles, keyed taper shafts and hubs. Such attached members are subjected to fluctuating loads, as from vibrations, or from rotating loads. Load variations and deformation under stress cause the slight movement that seems to be necessary for oxidation.

The conclusion of the author is that this factor of oxidation wear is not confined to ball and roller bearings, but occurs on steel parts where or when high load and low slip are present or permitted.

* Research Laboratories, General Motors Corporation, *Mechanical Engineering*, June, 1937.

American Society for Testing Materials Annual Meeting

THE Fortieth Annual Meeting of the American Society for Testing Materials, to be held at The Waldorf-Astoria, New York City, on June 28 to July 2, will include an address by the President, A. C. Fieldner, Chief, Technologic Branch, U.S. Bureau of Mines, on the subject " Fuels of To-day and To-morrow," and also the Twelfth Edgar Marburg Lecture on " Plastics : Some Applications of the Different Classes, Methods of Testing," to be delivered by Dr. T. Smith Taylor, Professor of Physics, Washington and Jefferson College. Throughout the week of the meeting there will be in progress the Fourth A.S.T.M. Exhibit of Testing Apparatus and Related Equipment in which leading organisations in the instruments and laboratory supply and related fields will display new developments.

In his presidential address on " Fuels of To-day and To-morrow," to be presented at the formal opening session on June 28, Dr Fieldner will deal with may important points which should be of interest to engineers and technologists in a wide range of industrial fields. Prior to his present office as Chief, Technologic Branch, U.S. Bureau of Mines, he was for many years Chief Engineer of the Experiment Stations Division of the Bureau.

Dr Fieldner proposes to consider the present uses of fuels, solid, liquid and gaseous in such fields as public utility power, lighting and heating ; transportation, including railroads, motor-vehicles on roads, marine, aviation ; industrial heating and power ; and domestic heating. An interesting part of his address will be that involving future trends in fuel utilisation. He will deal especially with automotive fuels, discuss supplementary sources of petrol, such as oil shale, hydrogenation of coal, synthesis of motor-fuel from water gas and steam, mining of oil sands, and fuels from renewable sources such as the alcohol from fermentation of vegetable matter. He plans also to outline the potential national fuel situation 25 years hence by discussing the fuel demand and supply, and also the chemical transformation of fuels to suit the demand-fuels made to order.

In the Twelfth Edgar Marburg Lecture, to be delivered on June 30, Dr. T. Smith Taylor will discuss the properties of the different classes of plastics and particular applications. The advantage of certain materials for specific applications for both the thermo-plastic and thermal-setting materials will be covered. He will summarise the test methods now available and used for certain materials, and probably indicate the necessity for specific methods of test for each class of materials in order to show their special properties. Attention will be directed to the development of test methods which are now in use, and to ways and means by which tests can be developed to apply to materials for which present tests are not suitable. He will give some consideration to the usefulness of test procedures.

The Determination of Working Time on a Steckel Mill

By a Special Correspondent

In this article a practical method is developed for calculating the time involved in rolling strip on a Steckel mill which can be applied to suit the conditions in any particular works.

THE importance of determining in advance the working time involved in carrying out a particular operation needs no emphasis; it is well known how valuable it is, not only in planning, fixing fair piece-work rates, etc., but for improving production processes. It may be of interest therefore to learn how working time can be determined in cold-rolling strip steel on a Steckel-type mill, especially as this type of mill was described in one of the last issues of this journal.

The method described is not claimed to be a highly scientific one, and the figures given should be regarded as examples, although they proved correct in practice. It will be appreciated that figures must be developed with special regard to the different working conditions peculiar to particular works.

The working time of a certain job is composed of:

1. Starting time.
+2. Rolling time.
+3. Reversing time.
+4. Finishing time.
+5. Lost time.

Time studies have shown that the lost time—*i.e.*, time of the unavoidable delays connected with each human activity—has to be taken as 12·5% of the four other times together.

Starting time, finishing time and reversing time per pass are nearly constant, and independent of the nature of the job. Including the respective part of the lost time, they are found by time studies as follows: Starting time, 7 mins.; finishing time, 11 mins.; reversing time, per pass, 1·6 mins. The sum of these three times of a certain job can be taken from graph, Fig. 1, if the number of passes is known. The number of passes necessary for a certain job can be determined by graph, Fig. 2, if the original thickness t_a, the demanded thickness t_n, and the average percentage of reduction per pass x are known.

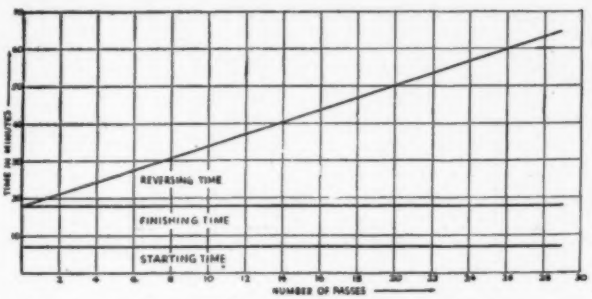


Fig. 1.—Starting, finishing and reversing time in minutes at a Steckel mill.

The rolling time can be determined by Table 1, with the help of the original length l_a of strip. This length l_a can be calculated with the equation—

$$l_a = \frac{\text{Weight of the coil}}{\text{Width} \times \text{original thickness} \times \text{specific weight.}}$$

It can be taken from suitable tables or from graphs, as shown in graph, Fig. 3.

Graphs shown in Figs. 1 and 3 are so simple that it is not necessary to explain how they are made. The construction of graph, Fig. 2, and Table 1 will be explained later, after an example is given to show how easy it is to determine the working time of any job with these auxiliaries.

A coil of 560 lb. weight, of material 3·75 in. wide and 0·083 in. thick, is to be rolled into strip of 0·006 in. thickness. The quality of the material is such that, according to experience, an average percentage of reduction per pass of 10% is suitable.

TABLE I.

FACTOR FOR CALCULATION OF ROLLING TIME AT STECKEL MILL IN MINUTES.

This factor is calculated for V, the average rolling speed equals 400 ft./min., and includes 12·5% lost time. Rolling time = factor × l_a. The actual rolling time is to be calculated by multiplying the table factor with the length of strip at the beginning of rolling in feet: l_a

$$\text{Rolling time} = \frac{1{\cdot}125 l_a}{V} \cdot \frac{1 - \left(\frac{1}{1 - \frac{x}{100}}\right)^n}{-\frac{x}{100}}$$

Reduction %	No. of Passes. 1	2	3	4	5	6	7	8	9	10	11	12	13
8	0·0031	0·00633	0·00985	0·0141	0·0181	0·0234	0·0284	0·0339	0·0399	0·0480	0·0538	0·0618	0·0728
10	0·0031	0·00660	0·0104	0·0147	0·0195	0·0250	0·0306	0·0369	0·0444	0·0525	0·0614	0·0714	0·0855
12	0·00315	0·00670	0·0108	0·0155	0·0207	0·0269	0·0335	0·410	0·0498	0·0596	0·0710	0·0840	0·0985
14	0·00325	0·00705	0·0114	0·0165	0·0225	0·0289	0·0376	0·0468	0·0575	0·0703	0·0850	0·1140	0·1210
16	0·00335	0·00730	0·0120	0·0176	0·0242	0·0325	0·0418	0·0530	0·0664	0·0825	0·1015	0·1240	0·1510
18	0·00340	0·00757	0·0128	0·0187	0·0267	0·0363	0·0472	0·0610	0·0778	0·0985	0·1240	0·1544	0·2145
20	0·00350	0·00788	0·0134	0·0198	0·0287	0·400	0·0530	0·0697	0·0905	0·1165	0·1495	0·1900	0·2420

Reduction %	No. of Passes. 14	15	16	17	18	19	20	21	22	23	24	25
8	0·0795	0·0897	0·1010	0·1150	0·1265	0·1395	0·1550	—	—	—	—	0·2535
10	0·0945	0·1083	0·1235	0·1400	0·1500	0·1797	0·2025	—	—	—	—	0·3625
12	0·1100	0·1333	0·1545	0·1755	0·2045	0·2425	0·2685	—	—	—	—	0·5270
14	0·1447	0·1972	0·2035	0·2385	0·2815	0·3300	0·3865	—	—	—	—	0·8225
16	0·1830	0·2210	0·2665	0·3175	0·3755	0·4580	0·5520	—	—	—	—	1·3700
18	0·2375	0·2940	0·3520	0·4440	0·5460	0·6690	0·8200	—	—	—	—	2·2500
20	0·3230	0·3860	0·4850	0·6100	0·7670	0·9600	1·207	—	—	—	—	2·7050

Graph, Fig. 2, gives a number of passes : 25.

Graph, Fig. 1, gives starting, finishing and reversing time : 58·5 mins.

Graph, Fig. 3, gives original length : 530 ft.

Table 1 gives a factor 0·3625—

Rolling time, equal original length × factor
= 530 × 0·3625 = 192 mins.

Working time of the job—
58·5 + 192 = about 250 mins.

It should be clear from this example that graph, Fig. 2, and Table 1 can be used without understanding how they are built up ; but if this method should be used under different working conditions, it is necessary to understand how the figures are developed. This may be explained as follows :

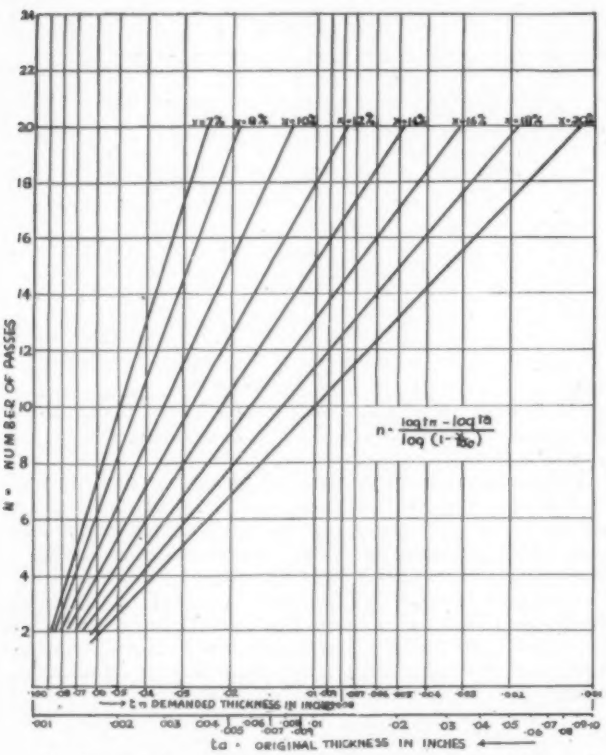


Fig. 2.—Number of passes at Steckel mill against original and finished thickness of strip in relation to different percentages of reduction.

If the original thickness is t_a, the thickness after the first pass t_1, the second pass t_2, and the last pass t_n, the average percentage of reduction = x, we have the following equations :

$$t_1 = t_a\left(1 - \frac{x}{100}\right)$$

$$t_2 = t_1\left(1 - \frac{x}{100}\right) = t_a\left(1 - \frac{x}{100}\right)^2$$

$$t_n = t_a\left(1 - \frac{x}{100}\right)^n$$

$$n = \frac{\log t_n - \log t_a}{\log\left(1 - \frac{x}{100}\right)}$$

Graph 2 shows this equation :

If the length after the first pass is l_1, the thickness t_1 ; after the second pass is l_2, the thickness t_2 ; after the last pass is l_n, the thickness t_n, and if the average rolling speed is V we have the equation for the rolling time T_r.

$$T_r = \frac{l_1}{V} + \frac{l_2}{V} + \ldots + \frac{l_n}{V} = \frac{1}{V}(l_1 + l_2 \ldots + l_n)$$

The volume of the material remains practically unchanged. Therefore it is—

$$l_a \times t_a = l_1 \times t_1 = l_2 \times t_2 = \ldots = l_n \times t_n$$

$$l_1 = \frac{l_a \times t_a}{t_1} \quad l_2 = \frac{l_a \times t_a}{t_2} \ldots l_n = \frac{l_a \times t_a}{t_n}$$

$$T_r = \frac{l_a}{V}\left(\frac{t_a}{t_1} + \frac{t_a}{t_2} + \ldots + \frac{t_a}{t_n}\right)$$

As we have seen above, it is—

$$\frac{t_a}{t_1} = \frac{1}{1 - \frac{x}{100}} \qquad \frac{t_1}{t_2} = \frac{1}{1 - \frac{x}{100}}$$

There—

$$\frac{t_a}{t_2} = \frac{1}{\left(1 - \frac{x}{100}\right)^2} \ldots \frac{t_a}{t_n} = \frac{1}{\left(1 - \frac{x}{100}\right)^n}$$

By putting this into the equation for T_r, we find after some transformation—

$$T_r = \frac{l_a}{V} \times \frac{1 - \left(\frac{1}{1 - \frac{x}{100}}\right)^n}{-\frac{x}{100}}$$

Taking from time studies the lost time as 12·5% of the other parts of the working time (see above), and the average rolling speed V = 400 ft. per min., we find—

$$\text{Rolling time} = l_a \times \left(\frac{1{\cdot}125}{400} \times \frac{\left(1 - \frac{1}{1 - \frac{x}{100}}\right)^n}{-\frac{x}{100}}\right) = l_a \times \text{factor}$$

Table 1 gives this factor for the different numbers of passes n, and the different percentages of reduction x.

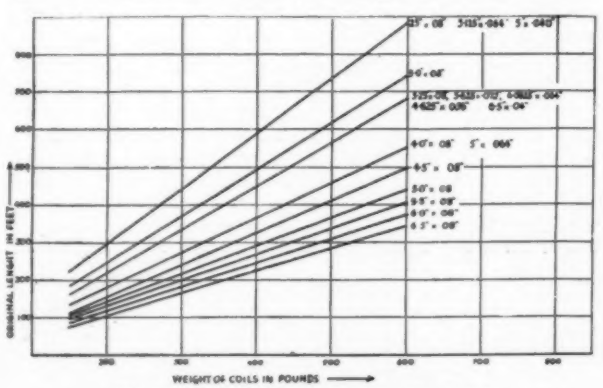


Fig. 3—Determining original length of strip.

As already mentioned above, the method is not a scientific one ; it is certainly possible to find a more elegant solution of the problem, but it is doubtful if it would be more suitable for practical use ; and that is what matters in this case.

High calorific value and the ease with which the temperature of the combustion space can be regulated render oil particularly suitable for firing furnaces and for melting charges requiring a close degree of temperature control. In a booklet recently issued by the Morgan Crucible Co., Ltd., Battersea Works, London, S.W. 11, is published a description of a large number of types of melting furnaces fired by oil fuel, some of which are also supplied for use with coke or town gas. Of particular interest is the last twelve pages in the booklet, in which are reproduced photographs showing actual installations ; these present very attractive lay-outs. Copies of this booklet are available from the Morgan Crucible Co., Ltd.

METALLURGIA
THE BRITISH JOURNAL OF METALS.
INCORPORATING "THE METALLURGICAL ENGINEER"

The Foundry Personnel

Its Recruitment

FROM time to time complaints are made in every industry and trade that the right type of recruits is not being obtained to maintain or improve the quality of its personnel. Every trade and industry wants the type of youth which is likely to contain among its ranks a good proportion who can be developed into controlling and directing executives and the foundry industry is no exception, but the powerful language on the subject used by Mr. C. W. Bigg, in his Presidential address at the Annual Convention of the Institute of British Foundrymen, leaves us no option but to assume that the foundry industry is very badly served in this respect.

The statement that the quality of youths entering founding is lower than that of those entering the engineering trades for such occupations as fitting, turning, etc., was used in a similar sense 30 or 40 years ago and the very people who were then included in that assertion are those largely responsible for the developments achieved in the foundry during recent years. Yet the writer finds himself in greater agreement with the statement in its application to-day than 30 or 40 years ago, and an explanation is not easy. Perhaps the foundry industry is encountering a period of transition from one in which craftmanship was essential to one consisting of a number of mechanical operations. The craftsman moulder, due no doubt to his ancient ancestry, is very conservative, and, generally speaking, is not favourably disposed towards mechanical developments, however much they may remove the graft from his craft. He is, of course, not alone in this respect. The tremendous advance in economical production has created a modern problem of machinery in relation to mankind, and in recent times, technical progress has obtained a lead which finds no practical comparison in the economic history of past centuries—it has become the most interesting phenomenon of these phenomenal times in which we live.

Many foundries are now well-organised, well-equipped, and run on modern lines, some are designed on scientific lines and production becomes more or less automatic. In such plants there is no room for the craftsman, apart from the preliminary work of preparing the pattern or pattern plate, locating runners and risers, etc. It has been said that moulders are not required with such mechanical plant and there are instances where unskilled labour has apparently satisfied conditions; in such instances the intelligent man with a mechanical turn of mind is likely to be more suitable for an executive position than the moulder, however high the craftsmanship of the latter. Even in foundries that still largely depend upon expert craftsmanship it is frequently found that directional ability is possessed by an inferior craftsman and he is able to exert efficient control without the sacrifice of the regard of the men in his charge. It is probably true, however, that practical foundrymen seldom achieve or even aspire to a place in the direction of the foundry industry.

Modern progress, which is responsible for the development of the different forms of specialisation, organisation and mechanisation, has reduced the proportion of foundry craftsmen; the work has been split up into various sections for economical reasons and few foundries have the facilities for training an efficient foundryman, even those which have are loth to make arrangements for apprentices to be adequately trained. It has long been the writer's opinion that promising young moulders should have access to the drawing office, just as, in some exceptional instances, the training of a draughtsman includes some time worked in a pattern-shop and foundry.

That the higher executives in the industry should have a good leavening of practical knowledge, none will deny; but is there not a tendency to train craftsmen on the one hand, with little or no knowledge of science, and, on the other, highly skilled technicians with no practical experience? Is it to be wondered at that they fail to understand one another? It is this method of training which gives rise to mutual distrust. Efficient and competent foundrymen should have a sound knowledge of the principles and processing methods, which includes the ability to give sound advice in the drawing office, in order to facilitate the work in the foundry and possibly in the machine shop, and capable of directing all the operations required up to and including the dispatch of the castings. This does not mean that they should be competent to execute every operation with a skill equal to those who have specialised in a particular process or operation. Thus, there is no reason for the suggestion that executives should necessarily graduate from the foundry floor, though experience of this character is very valuable.

In discussing factors which are likely to contribute to the improvement in the quality of recruits to the foundry, it is no doubt true that a well-organised, well-equipped and well-run industry would contribute and provide suitable conditions to enable the industry to compete successfully for the best among the recruits of industry. It is surprising however, how boys are attracted by the ambition to be an engineer, although it may not extend beyond being a fitter, turner or a machinist, while the foundry has no such attraction. Changing this outlook will involve years of patient work, which has already begun in our technical schools.

The conditions favouring a solution to the problems of the foundry personnel have been improved in recent years and the Institute of British Foundrymen has done and is doing excellent work to this end. It has brought together men who are interested in the many sections of the foundry industry, and fostered the presentation of problems from a common platform, for discussion without reserve, in an effort to provide solutions. It has used its influence and support to increase educational facilities throughout the country, so that youths working on the floor may have the opportunity to acquire the technical knowledge now so necessary in the production of castings, and there are indications that its efforts have improved the status of foundrymen.

The success of all efforts to improve the status of those engaged in foundry work, however, must, of necessity, depend upon each individual foundryman. It is he who can bring the greatest influence to bear upon those with

whom he is in intimate contact in the foundry. Not enough personal interest is taken in the youths at present employed, even by those who are desirous of raising its status. The best support the Institute can have in its efforts to improve the personnel of the foundry is to decide upon a plan of action in individual foundries and call upon its members to carry out its suggestions with such thoroughness as is bound, ultimately, to have an uplifting effect, and with such a vigorous personality as Mr. Bigg behind the movement, conditions in the foundry would gradually improve and become as attractive as other industries, and acquire a status equally as high.

Aluminium Development in Switzerland

SWITZERLAND is one of the smallest countries of Europe which in recent years has in the average man's estimation been more important for its production of suggested solutions of international problems than as an industrial country. It is not a country rich in natural resources by comparison with Great Britain and this has made it the more necessary to develop to the utmost those which it possesses. It is fortunate with regard to aluminium and, like Norway and Canada, has an inexhaustible water supply, without which it would be impossible to produce annually 200-230 kilog. of the metal. It is in the Haut-Vallais that aluminium is actually produced and Neuhausen may be described as the cradle of the aluminium industry on the Continent, where it has been a developing industry for over a period of many years.

Neuhausen is really the administrative centre of the Swiss aluminium industry and there are there large well equipped laboratories, foundries and other workshops. During the rapid development in the use of aluminium throughout the world Neuhausen has become more and more important, particularly as a centre of research work, and it is sometimes claimed to be an international aluminium centre. It is probably correct to say that for production of aluminium on a large scale the use of water power is of greater importance than to have works situated in the neighbourhood of bauxite deposits.

It would, however, be a mistake to conclude that production depends essentially, with regard to cost, on power, because this constitutes only 16 to 18% of the cost of production. The dominant position of the industry in Switzerland is a result of 40 years of technical, practical and commercial experience. Without doubt this development has been largely assisted by the importance attached to the subject of metallurgy in the secondary schools. It has always been considered as an almost essential part of a scientific education to have a knowledge of metallurgy.

Aluminium is not, of course, the only metal exported in quantity by the country but in some respects it is the most important and has a powerful influence on the economical position of Switzerland. It is of interest to note that while it is not as important in the home market as the older non-ferrous metals like copper, tin, lead, and zinc, it occupies the premier place with regard to export trade. Actually the value of aluminium used in Switzerland at the present time is in the neighbourhood of five million francs whereas the value of the exports is about 60 million francs. It is probably correct to say that the larger proportion of the exports is in the form of finished goods, probably 65 to 70%. Up to 1928 the value of exports showed a steady increase over a period of many years, but afterwards and at least until 1932 the curve fell rapidly, this being partly due to the necessity forced upon other countries of developing their own aluminium industries, owing to national defence needs. The value of exports fell in 1936 to 36 million francs, which represented by comparison with 1928 a reduced value of 24 million francs, while in the last year the quantity exported was 223,000q or actually 14,000q more.

Industries for the manufacture of aluminium finished goods were being developed as rapidly as the production of the actual metal was increasing, and to-day the manufacture of semi-finished articles in aluminium and also hardware and other finished aluminium goods is of the greatest importance to the country. In Switzerland itself very great use is being made of aluminium in several industries and it is significant that a large proportion of vehicles under the control of the post office have aluminium bodies, the claim being made that for the rapid traffic of the Swiss post office the use of aluminium to reduce load carrying is indispensable.

To realise the part played by the aluminium industry in the national economy it is only necessary to review the whole world position with regard to the lighter metals. It is precisely this consideration which explains the falling away of export figures in 1928 and 1932. As a commentary on the world depression it is of interest that in spite of the increase of exports the value scarcely increased at all and this also directs attention to the international market for light metals. The Swiss Industry claims that the high quality and the very exceptional standing of the industry is the result largely of the attention given to the manufacture of articles for export while the industry is also supported on the technical side by the large amount of research work that is undertaken in order to discover new applications for the metal.

Society of Chemical Industry Conference

Questions ranging from the problems of alloy cast irons to the utilisation of waste fruit will be discussed at the 56th Annual Meeting of the Society of Chemical Industry which will be held at Harrogate from July 5 to July 9, under the patronage of the King.

It is expected that more than 500 scientists will be attending the meeting. They will come from practically every industrialised country in the world. Many important questions will be discussed and among the technical papers to be presented it is noteworthy that Dr. A. B. Everest will give latest information on the special properties of the new class of alloy cast irons as material for chemical plant. The Society's presidential address will be delivered by Lord Leverhulme.

An attractive programme of excursions covers such varied industries as cocoa and chocolate manufacture, oil and cake mills, clothing manufacture, and the making of solid drawn metal tubes. Members of the conference will be enabled to visit Wharfedale and Nidderdale, and many special facilities are being provided by Harrogate Corporation.

Restoring Ancient Iron Objects

A REMARKABLE example of the restoration of old iron is to be seen at an exhibition in Leningrad at the Institute of Archaeological Technology, opened on the occasion of the 18th Session of the Marr Academy of the History of Material Culture. Among the exhibits is a piece of rusty and shapeless iron next to several links of a wrought-iron chain of the early Byzantine period. They were all taken from the same object, but the links had been restored by a process invented at the Institute, while the shapeless piece was left in the condition in which it had been found. The Institute claims that articles hundreds and thousands of years old can be restored to their original shape by this process. It consists roughly of the following: To clear the age-long incrustation of an article discovered during excavations, it is boiled for some time in water and a weak solution of formic acid, after which it is restored by an electrolytic process and then subjected to special treatment by fat, which restores its original freshness. This new method, it is said, will enable museums to preserve vast collections of historically valuable iron objects, which would otherwise have been doomed to gradual destruction.

Some Heat Treatments of Whiteheart Malleable Cast Iron

By JOHN V. MURRAY

Blackheart and Whiteheart malleable cast irons are discussed and reference made to the handicap under which the latter is manufactured. The need for control is stressed and the high tensile strength of Whiteheart malleable made under such conditions is emphasised. Experiments on Whiteheart malleable are described covering a range of heat-treatments and the results given show that, with proper control in manufacture, this type of malleable cast iron has a wide field of usefulness.

RECENTLY it was stated that Blackheart malleable castings had doubled in output during the last few years, whilst Whiteheart had stood still. The statement was not untrue, and it is surprising. Blackheart castings were comparatively unknown in this country on a commercial basis a few years ago, and the makers of this type of malleable are to be congratulated upon the progress attained. The writer attributes this progress to the following :—

(1) The careful control of the material by the laboratory chemist.

(2) Improved methods of melting, *i.e.*, open hearth, rotary furnaces or the duplex system of melting in a cupola and refining in another furnace, and

(3) Scientific control with lower temperature anneal, and inert packing, making this heat treatment a much cheaper one than the Whiteheart Anneal.

Factors Affecting Cost

This method, being cheap, contributes not a little to the successful advance of the Blackheart type of casting. There is less fuel used, no expensive ferric oxide is used, whilst the life of the annealing can is very much longer ; also the wear and tear of the furnace is less, so it appears that this condition of affairs will persist because of the economics of production. This article is not written with a view of taking sides as to which is the best kind of malleable cast iron. There is a field for both types, but the makers of Whiteheart are under a handicap when they have to compete with cupola melted iron (usually uncontrolled) against open hearth melted iron by the Blackheart makers. Crucible melted malleable is the finest Whiteheart that can be produced, but its price and limited quantities prohibit its general use.

It may be safely assumed that if (1) and (2) are applied to both types, then the third factor would still give the Blackheart malleable an advantage. As the cupola is the cheapest kind of melting furnace, it will still prevail, but this is the one particular furnace which needs proper control. A chemist is a necessity. Guessing at the composition is wrong. The casting of a 3 in. plug and noting its fracture helps, but to keep this white, or just ticked with graphite is only correct when the castings are similar in size and section. To compare a 3 in. fractured plug against a $\frac{3}{8}$ in. sectioned casting is futile. The fracture does not always correspond with composition. Very often it corresponds to furnace conditions, and which will probably be altered next day. This particular condition is only found after the castings are annealed. They break with the least effort, and show an oxidised blue fracture. Cupola melted malleable should always be controlled by composition. This is not a difficult job to the malleable metallurgist. With controlled melting very consistent results may be obtained. The annealing operation should also be scientifically controlled with suitable pyrometers, assisted by the microscope. Then there would be fewer complaints about the quality of the material, and as this improved, there would be a greater demand for it, or for even better iron.

Whiteheart Malleable and Engineers

Many engineers and users of Whiteheart malleable cast iron do not make the best use of it. There is no apparent reason why good malleable cast iron should not give a tensile strength of 50 tons per sq. in. The author spent a few years in charge of a malleable melting and annealing plant where castings from 2 in. to 6 in. in section were quite common. They weighed from a few lbs. up to three or four cwts. Three in particular were 9 in. in section and weighed 5 cwts. each. These latter were troublesome, but with the aid of steel and sulphur a white casting was produced at the second attempt. Good material and easy machinability were demanded from these castings which formed part of some heavy machinery. They were heat-treated to give exactly the service demanded.

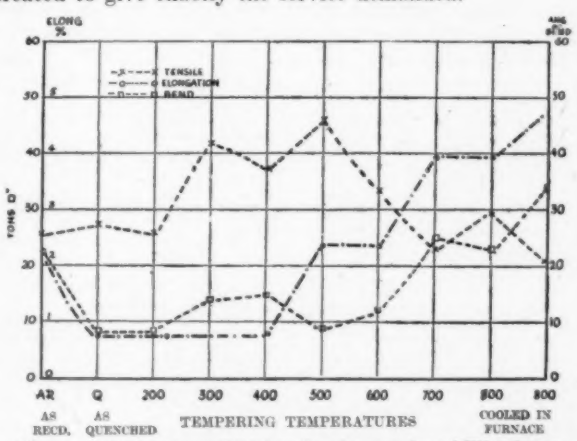
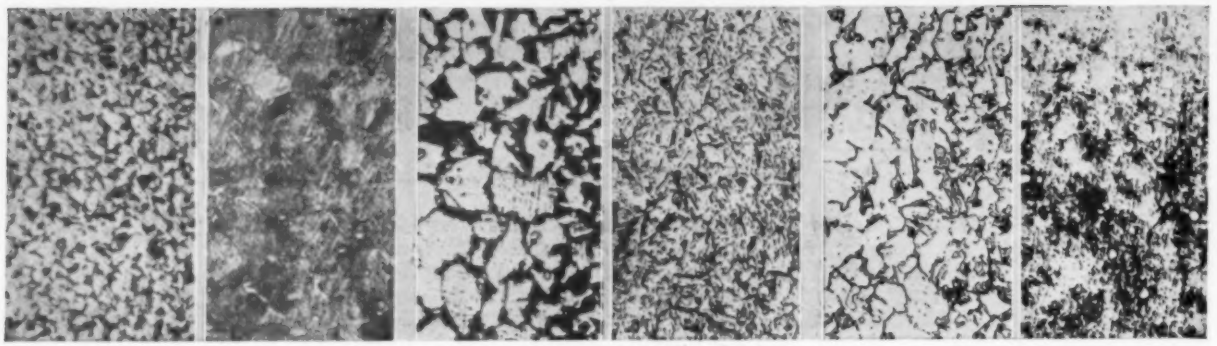


Fig. 1.—Effect on quenching in oil and tempering of Whiteheart Malleable Cast Iron.

Whiteheart malleable cast iron is actually steel produced by a dry method. Chemical composition is practically the same throughout for thin castings. For thicker castings a change takes place as one proceeds from the outside to the interior. A progressive amount of pearlite with increasing amounts of nodular carbon is found. Hence greater care must be exercised in the heat-treatment of Whiteheart malleable than in steel. The treatment depends absolutely upon the amount of decarburisation which has taken place. This is to say, the treatment given to a four days full anneal, exclusive of heating and cooling must be different from one annealed for six days in order to produce the same results.

Some Experiments

The following experiments were carried out upon four days' annealed samples, *i.e.*, 96 hours at 980–1,000° C., 24 hours were occupied in reaching 980° C. and 36 hours in cooling down to about 250 when they were withdrawn. The oxidising mixture was five parts old used ore to one of new red ore (Fe_2O_3). The furnaces were pyrometrically controlled and the metal was a charge composed of 25% steel, 25% hæmatite pig iron and 50% shop scrap, runners, gates, etc.



OUTER ZONE CENTRE
Sample 1.—As received from furnace.

OUTER ZONE CENTRE
Sample 2.—Heated to 900°C and quenched in oil.

OUTER ZONE CENTRE
Sample 3.—Quenched in oil and tempered at 200°C.

The resultant melt was as under :—

Si, 0·51. S, 0·136. P, 0·042. Mn, 0·24, T.C., 3·44.

The melting furnace was the cupola. The work was done in triplicate. Three B.E.S.A. test bars and bend tests were carried out and the results give the average tests of the three bars. Other tests were carried out, but with a full six days' anneal excluding heating and cooling. These results are given in Tables I. and II., and in the graph, Fig. 1.

All the samples were quenched in oil from a given temperature and tempered at varying temperatures. Microphotographs were taken and are reproduced. The moulding and annealing were done by a firm in Birmingham, whilst all the heat-treatments and microscopic tests were conducted in the Research Department of the County Technical College, Wednesbury.

Analysis of Results

Quenching in oil at 900° C. while slightly raising the tensile strength, has considerably reduced the malleability. Tempering at 200° C. has probably relieved quenching strains and not altered mechanical values, but tempering at 300° C. very much increases the tensile strength. Also No. 5 bar at a tempering of 400° C. Up to this point the malleability remains more or less constant. With tempering at 500° C., the strength rises at 46·2 tons per sq. in., whilst the elongation is restored to its original value of 2·34%. From this point the malleability increases, but the strength begins to drop to normal. It is notable that tempering at 700° the strength is only 23 tons per sq. in. This is of course, the temperature of spheroidisation or graphitisation as the case may be. Tempering at 800° evidently causes a solution effect, and the strength increases greatly and at 900° the effect of slow cooling in the furnace is shown by the reduction of the tensile strength, and an increase in malleability.

Microscopical Examination

The photo micrographs were X 200 diam. and were etched in a 3% nitric acid and 3% picric acid solution, or in a 3% nitric acid. This latter reagent was suitable for the hardened samples—picric acid did not attack these, or only very slightly. The outer section and the centre were photographed.

SAMPLE 1 AS RECEIVED FROM FURNACE.

Outer Zone. A fine mixture of pearlite and ferrite grains merging on one side to an area of pure ferrite and to another inner side of saturated pearlite.

Centre. A structural mass of pearlite, very fine with a few veins of ferrite and some coarse nodular carbon. Inside these nodules could be seen a few specks of cementite. Such a structure is slightly under annealed and would not give good bending values or elongation.

SAMPLE 2. HEATED TO 900° C. AND QUENCHED IN OIL.

Outer Zone. The peculiarity of this micro is the presence of troostite veins and ferrite.

Centre. A mass of martensite in austenite. No cementite could be seen inside the nodular carbon.

SAMPLE 3. QUENCHED IN OIL, TEMPERED AT 200° C.

Outer area. The troostitic veins have made their escape by diffusion and relief has expressed itself in a finer structure.

Centre. This is still austenitic but some movement has taken place of carbide.

SAMPLE 4. TEMPERED AT 300° C.

The structure is still very fine and the carbides are breaking down. It is still martensitic plus austenitic and some free carbides. It is too hard for machining. The outer zone appears to be ferrite whilst the centre commences to break down.

SAMPLE 5. TEMPERED AT 400° C.

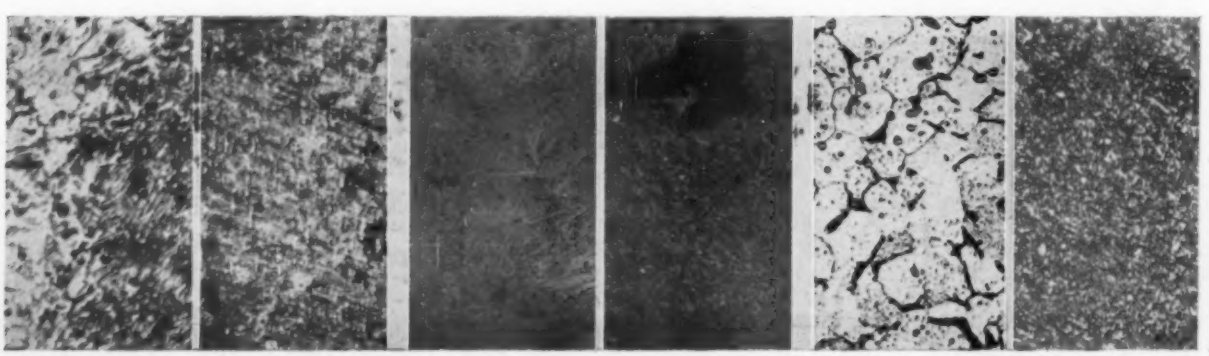
Carbon has diffused almost to the edges. The structure is very fine.

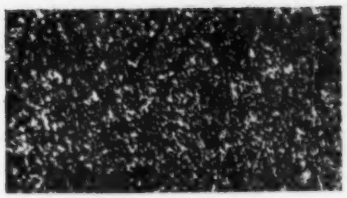
In the dense centre austenite has almost disappeared, and the transformation of martensite has commenced. The metal is still hard and more or less brittle.

Sample 4.—Tempered at 300°C.
OUTER ZONE CENTRE

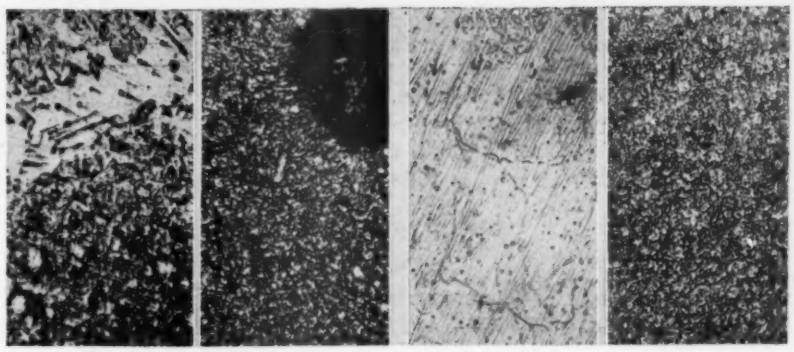
Sample 5.—Tempered at 400°C.
OUTER ZONE CENTRE

Sample 6.—Tempered at 500°C.
OUTER ZONE CENTRE





Structure of 1.0 per cent carbon steel; note similarity with Sample 7, centre.



OUTER ZONE CENTRE OUTER ZONE CENTRE

Sample 7.- -Tempered at 600°C. *Sample 8.—Tempered at 700°C.*

SAMPLE 6. TEMPERED AT 500° C.

Outer Zone. This is ferrite with a few spots of ferrous sulphide with an oxidized layer on the extreme edge.

Centre. This is very fine and is martensitic-troostic-sorbite structure while nodular carbon appears to disintegrate and become very small. It was studded with a large number of small bits of free cementite.

SAMPLE 7. TEMPERED AT 600° C.

This is also a very fine structure and quite comparable with 1·00% C steel. The inner area is breaking down into free ferrite and the inside is now composed of ferrite and pearlite in a finely divided condition. The nodular carbon is reasserting itself. The photo micrograph of a 1·00% C steel is given for comparison.

TABLE I.
EFFECT OF TEMPERING TEMPERATURES.

Bar No.	Heat Treatment.	T.S., Tons per Sq. In.	% Elongation on 2 in.	Angle of Bend.	Fracture.	Remarks.
1	As received from furnace	26·03	2·34	23°	White, steely, fine centre, outer crystalline ring	—
2	Quenched at 900° C.	27·73	0·78	8°	White, cupped skin	Cup effect
3	Do. Temp. 200° C.	26·00	0·78	8°	White, cupped skin	As above
4	Do. do. 300° C.	41·78	0·78	14°	White, picture frame of bright grains	—
5	Do. do. 400° C.	37·92	0·78	15°	White, very fine centre, as above	—
6	Do. do. 500° C.	46·21	2·34	9°	Grey, dirty bull's-eye, as above	—
7	Do. do. 600° C.	33·93	2·34	12°	Completely blackish grey, cup effect	—
8	Do. do. 700° C.	23·00	3·91	25°	Fine grey, specks of white in centre	Cupped
9	Do. do. 800° C.	29·45	3·91	23°	White outer, grey centre, picture frame	—
10	Do. do. 800	21·63	4·69	34°	Outer white cup, dirty grey inner zone	Cooled in furnace

TABLE II.
EFFECT OF TIME AND TEMPERING TEMPERATURES.

Average of 3 Bars.	Time of Anneal.	Treatment after Oil Quenching at 900° C.	T.S. Tons per Sq. In.	% Elongatiin on 2 in.	Angle of Bend.
No.					
1	144 hours	Tempered at 400° C.	38·1	Nil	—
2	Do.	Do. 500° C.	28·1	2·95	—
3	Do.	Do. 600° C.	33·3	3·42	—
4	Do.	Do. 700° C.	29·6	4·69	35°
5	Do.	Do. 750° C.	26·1	4·69	63°
6	Do.	Do. 800° C.	26·8	7·03	35°
7	Do.	Do. 850	27·5	3·12	52°
8	Do.	Do. 900	23·9	5·73	42°

SAMPLE 8. TEMPERED AT 700° C.

Outer Zone. The ferrite grains are very large now and are not refined, but the centre is a very fine structure. Spheroidisation has commenced with a loss in tensile strength.

SAMPLE 9. TEMPERED AT 800° C., TREATMENT AS STATED.

The peculiarity of this treatment is the refining of the ferrite grains, and the further diffusion of carbon in an inner zone. This helped to break up the large ferrite grains as shown in No. 8. This inner zone is very fine and accounts for the increase of strength whilst the elongation remains the same. There are quite a lot of "blobs" of ferrous sulphide which are harmless in this form. Specks of cementite reappear in the centre again in a much better structure than in the as-cast specimen, and the cored structure has disappeared.

Other work is necessary upon this refinement of ferrite. A totally decarburised casting cannot be refined when grain size is large. The diffusion of carbon from the centre has probably caused the recrystallisation.

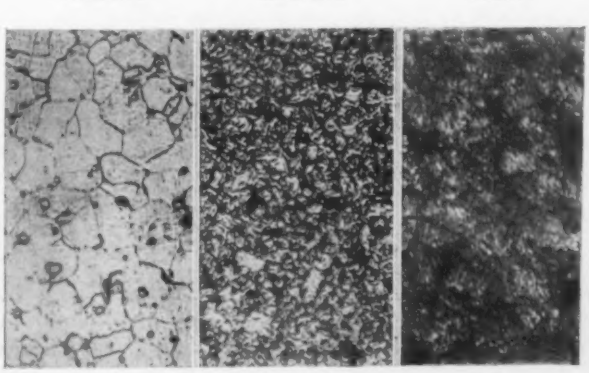
Uses for Hardened and Tempered Malleable Cast Iron

Obviously there is some use for these types of metal in the engineering world. For very heavy press work, heat-treated cam-rods and caps are called for. Crank shafts for pumps and slow moving machinery are made of this material. Edge tools such as shears (cutting) will keep their fine cutting edge quite as good as steel. The author has in his possession a pair of pruning scissors which have kept their sharpness for three years without any attention. Case-hardened malleable is well known by manufacturers, and it is hardly fair to stamp it with "Best Cast Steel." Give malleable cast iron the credit for its own performance. The author is aware of many buyers of steel castings, who are supplied with malleable cast iron, and it says something for the quality of the material, when it has never been questioned. This material was just normalised with a treatment at 900° C. and cooling on the floor. In one particular case a manufacturer of malleable castings purchased heat-treated malleable as steel, and swore by it. He could easily have made it very much cheaper himself. The hardened parts of malleable are intensely hard, wear for long periods, and are easily replaced when broken.

By using heat-treated malleable the weight may be cut down because the yield point is always high. This goes up to 80–95% of the breaking stress, and it must always

Sample 9.—Tempered at 800°C.

OUTER ZONE INNER ZONE CENTRE



be under the control of the metallurgist, and never left to empirical guesswork. It will always depend upon :—

(1) The amount of graphitisation and
(2) The amount of carbon in solution.

These depend upon the temperature and period of anneal, and the ore mixture used for decarburising.

Table II. shows the effect of a six-day anneal at 980° C. using synthetic ores only. By synthetic ores is meant old used ores treated suitably and reoxidised. The indiscriminate use of synthetic ores spoils many castings, and the chemist is a necessity. The amount of Fe_2O_3 present in the ores *must* be known. These ores contained 25% and were toned down with used ones.

It will be noted that tempering at 400° C., the strength is high but there is no elongation. The material could not be bent without considerable resilience. At 500° C. this property is recovered and is 3·12%. These figures are given in order that comparisons may be made, and will show that indiscriminate heat-treatments by non-technical operators is inviting failure.

Case-Hardened Malleable Cast Iron. Ordinary case-hardened malleable possesses a Brinell hardness of 400 approximately, when quenched. It can be made much harder by cementing for a further period. The same temperatures as for steel are always used. The following gives a series of case-hardened test bars (not machined).

No.	Load.	Tons per Sq. In.	Elongation on 2 in.	Bend °.	Brinell.
			%		
1	8·8	35·2	3·12	20	400
2	9·0	36·0	3·12	25	400
3	8·4	33·6	1·50	15	400

When these bars were normalised the bends were 80°. The carbon apparently dioxidised the outer layers of metal.

The strength was increased considerably but the elongation and the angle of bend were reduced. This, of course, was expected. The period of cementing was ninety minutes. They wear very well upon mechanical parts, and there is no reason why case-hardened malleable should not be used more extensively for many types of fittings where resistance to wear is required.

With care, Whiteheart malleable cast iron may be forged hot, welded, brazed, rolled hot or cold, rivetted hot or cold, tinned, sherardized, galvanised or plated without losing its intrinsic properties ; normalised or hardened and tempered as a normal steel and the author hopes to give further details of these later.

The author takes this opportunity of thanking the Staffs. Education Committee for facilities in taking mechanical tests and micro photography ; T. G. Bramford, M.Sc., Principal of County Technical College, Wednesbury, and members of the staff for their co-operation and helpful suggestions during the work.

Correspondence

Heat-Treatment and the Component

Sir,—It is, of course, difficult to keep a " Correspondence " strictly within the terms of the original reference, and appreciating this, I was inclined to leave Mr. Plant with his verdict, and accept it as a self-evident truth. Further perusal, however, indicates a fundamental difference in outloook, and this makes it all the more necessary (with your permission, sir) to attempt either the reconciliation of those outlooks, or accept complete divergence away from the original question.

My contention was the importance of the component as such, and Mr. Plant must be aware that there are many metallurgists not associated with steelmaking, whose activities are connected with, and are dependent on the manufacture of components. Such individuals are forced by circumstances to acquire an engineering education, for there are no water-tight compartments in a component which is causing trouble. To take an example, I am at present aware of a unit which is giving much anxiety to several responsible executives, all of whom, I can assure Mr. Plant, have made a thorough study of laws and theories. Moreover, they appreciate that such a study is a continuous process, and they are decidedly not in a state of specialist isolation.

In the making of this particular unit many are responsible ; it has the following life history :—

(*a*) Steelmaker and hot roller.
(*b*) Wire drawer and bulk heat-treatment.
(*c*) Component fabricator and secondary heat-treatment.
(*d*) User (designer and works metallurgist).

Each of these firms *a*, *b*, *c*, *d*, employ chemists and metallurgists and technical engineers, but metallurgist *d* is the connecting-link between them all, for his direct responsibility is connected with the component.

There are possibilities of trouble all along the line, and no one acquainted with elusive troubles will doubt the difficulty in giving slight and purely metallurgical irregularities, or, the obstacles in the way of an isolated responsibility, their correct significance. Most troubles of this kind are finally solved by a painful process of elimination, much co-operation and, even more, impingement of an individual's normal activities on those of another. The academic name for this is " Research "—the works director calls it " getting the darned job right."

A few more episodes may illustrate my point that the metallurgist must acquire an engineering education, or, at the very least, a knowledge of possible variables outside his own sphere, and this is surely postulated in Mr. Plant's " thorough study of laws and theories connected with the design, manufacture and working of metals."

CASE A.

Young foundry chemist (many years ago, and not possessing a volume meter), trying to connect cupola-silicon losses with blast pressure. He finally decided that all variables were largely dependent on the cupola man's desire to work overtime or, alternatively, to get away to a football match, and the tuyere areas were altered according to these very human considerations.

Note.—He was a very young chemist !

CASE B.

Metallurgist *b* reporting on cracked piston, for which metallurgist *a* was metallurgically responsible. He took drilling from skirt of piston and small section for microscopic examination. He reported very adversely on composition and structure, and explained failure thereby. Metallurgist *a* broke piston through the cracked crown, and found that the section, owing to core displacement, was only one-third specified thickness.

CASE C.

Metallurgist, investigating soft spots on small bush components, found decided raw material variations, and wasted much time in consequence. He finally found (helped by external assistance) that soft bronze feed fingers in the rod grinding machines were leaving an intermittent bronze smear on rods sufficient to retard carburising locally on these small components.

CASE D.

Sudden failure of rivetted ends on cycle-brake levers was found to be due to " blue brittleness " after enamelling, which had previously been eliminated by a high-temperature drying operation prior to enamelling, an operation which had been adopted for convenience, and was cancelled for a similar reason without notice.

All very simple, but indicating that the process of education is of slow growth and, with this proviso, perhaps Mr. Plant and myself do converge after all.

Yours faithfully,

May 30, 1937. H. T.

The Corrosion Problem and the Engineer

By F. HUDSON

The wastage of metals due to corrosion is an important engineering problem, and in this article the author outlines what might be termed the practical aspects of the problem, embracing particularly the corrosion of iron and steel structures as affected by sea and natural waters.

FROM the technical point of view one is apt, when first commencing a study of this problem of corrosion, to become rather alarmed at the numerous variables present and the lack of any recognised cut-and-dried test methods. No doubt these factors have been largely responsible in limiting research, except in isolated instances, to simple experiments of immersing metal specimens in various parts of the world in particular liquids, and noting results. The final result of such tests are of problematic value from the practical point of view, and if any serious advance is to be made, then it becomes essential to apply some originality on the matter, keeping in mind, as far as possible, the various factors entailed.

Briefly speaking, the factors which require consideration in connection with the corrosion of metals by industrial waters can be outlined as follows:

1. *Factors associated mainly with the metal.*
   - Effective electrode potential of a metal in a solution.
   - Over-voltage of hydrogen on the metal.
   - Chemical and physical homogeneity of the metal surface.
   - Inherent ability to form an insoluble protective film.
2. *Factors which vary mainly with the environment.*
   - Hydrogen-ion concentration (*p*H) in the solution.
   - Influence of oxygen in solution adjacent to the metal.
   - Specific nature and concentration of other ions in solution.
   - Rate of flow of the solution in contact with the metal.
   - Ability of environment to form a protective deposit on the metal.
   - Temperature.
   - Cyclic stress (corrosion fatigue).
   - Contact between dissimilar metals or other materials as affecting localised corrosion.

All these factors come into play when metals corrode, and they are intimately associated with either the properties of the metal or the environment, that is service conditions. To this list one may add a further factor, not actually intentionally associated with either metal or environment, but, nevertheless, often present, namely, the corrosion of metals by stray currents. A full discussion on all these factors would take more than the space available here, but it is of considerable importance that a general idea be obtained of those having a direct interest to the engineer.

In regard to the general mechanism of corrosion, it may now be regarded as established that in substantially all cases of corrosion at ordinary temperatures, and these comprise the most important practical cases, the driving force of the corrosion reaction between metal and environment is electro-chemical. The magnitude of the electro-chemical potential, which varies with the environment and the metal, determines the tendency of the reaction to proceed, whereas the rate of corrosion is determined mainly by the resistance to the continued progress of the reaction set up by certain of the corrosion by-products.

If two strips consisting of different metals are immersed in a solution or electrolyte free from heavy metal ions, and if the two strips are joined to the terminals of a galvanometer, an electric current will be registered on the galvanometer. The more reactive metal will function as the anode, and it will be corroded, whilst hydrogen ions will be forced on to the surface of the more noble metal, the cathode. This constitutes a simple corrosion cell, and illustrates the basic principle of the modern electro-chemical theory.

There is apt to be some confusion of the terms positive and negative in the study of corrosion cells due to the fact that there are two circuits; the external circuit which flows outside the cell from positive to negative and the internal circuit which flows inside the cell, through the solution or electrolyte in the opposite direction from negative to positive.

The degree of attack upon the anode is proportional to the current generated, and this in turn depends upon the factors already given.

Considering the metal first, it will be appreciated that in a stagnant or still solution no current is generated in a cell of this type when like metals, each in the same condition, are employed as electrodes. A potential is only developed when the equilibrium of either the solution or the metal combination is upset. The easiest way to upset equilibrium is to employ dissimilar metals as electrodes, and the current then generated varies according to the positions of the metals in the electro-chemical series, as shown in Table I. The noble metals not easily corrodable stand at the top and are assigned positive values, whilst the more reactive metals, easily corrodable, are given negative values, and are situated near the bottom of the table. If a cell is formed from metals having widely different normal electro-potentials then the current produced is correspondingly larger. For example, suppose a cell is from copper and iron, then a current is produced leading to corrosion of the iron, but by substituting gold for the copper a still larger current is generated with increased corrosion on the iron.

TABLE I. (U. R. Evans.)

ELECTRODE POTENTIALS OF METALS.

Metal.	Concentration of Ions.					
	Ion.	*N*.	*N*/10.	*N*/100.	*N*/1,000.	*N*/10,000.
		Volt.	Volt.	Volt.	Volt.	Volt.
Gold	$Au^{\cdots}$	+0·99 (?)	—	—	—	—
Platinum	$Pt^{\cdots}$	> +0·86 (?)	—	—	—	—
Silver	$Ag^{\cdot}$	+0·7987	+0·741	+0·683	+0·625	+0·567
Mercury	$(Hg^{\cdot})_2$	+0·7928	+0·764	+0·735	+0·706	+0·677
Copper	$Cu^{\cdot\cdot}$	+0·3469	+0·318	+0·289	+0·260	+0·231
(*Hydrogen*)	$H^{\cdot}$	±0·000	−0·058	−0·116	−0·174	−0·232
Lead	$Pb^{\cdot\cdot}$	−0·132	−0·161	−0·190	−0·219	−0·248
Tin	$Sn^{\cdot\cdot}$	−0·146	−0·175	−0·204	−0·233	−0·262
Nickel	$Ni^{\cdot\cdot}$	−0·20	−0·23	−0·26	−0·29	−0·32
Cobalt	$Co^{\cdot\cdot}$	−0·23	−0·26	−0·29	−0·32	−0·35
Iron	$Fe^{\cdot\cdot}$	−0·34	−0·37	−0·40	−0·43	−0·46
Cadmium	$Cd^{\cdot\cdot}$	−0·420	−0·49	−0·478	−0·507	−0·536
Zinc	$Zn^{\cdot\cdot}$	−0·770	−0·779	−0·828	−0·857	−0·886
Aluminium	$Al^{\cdot\cdot\cdot}$	−1·337	−1·356	−1·375	−1·394	−1·413
Magnesium (approx.)	$Mg^{\cdot\cdot}$	−1·8	−1·8	−1·9	−1·9	−1·9
Sodium	$Na^{\cdot}$	−2·715	−2·773	−2·831	−2·889	−2·947
Potassium	$K^{\cdot}$	−2·925	−2·983	−3·041	−3·099	−3·157

In each case the degree of current obtained should correspond momentarily with the difference in the normal equilibrium potentials.

Similarly, a metal below another tends to protect those higher in the series, and this is the reason why a coating of zinc protects iron and steel structures from corrosion.

It should be pointed out that complete unity of opinion has not yet been reached as to the exact position of some of the metals shown in this table, and also it is important to notice that the values of the electrode potentials given vary considerably with the surface conditions of the metal. The presence of a slight film of oxide, even too thin to be visible, may shift the equilibrium in a most surprising manner in the positive direction. Thus, iron in the "active" state with a clean, fresh surface, presents a more negative potential than "passive" iron such as is obtained under certain conditions. Obstructive films of this kind are said to have an ennobling effect upon reactive metals, rendering their behaviour somewhat similar to that of a noble metal. The increased corrosion resistance of the stainless iron and steels is due to their ability to rapidly assume a "passive" surface when in contact with many corroding media. Fig. 1 illustrates suitable apparatus for studying the potentials generated from simple corrosion cells embodying dissimilar metals.

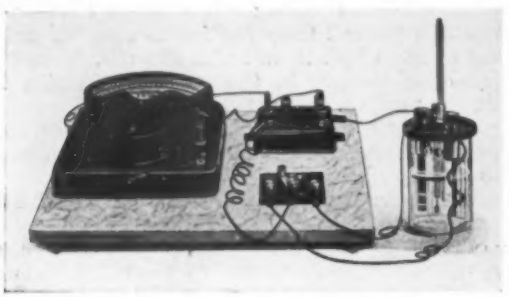


Fig. 1.—Tölt's apparatus for studying the potentials generated from similar corrosion cells embodying dissimilar metals.

Some very interesting results can be obtained on apparatus of this nature. For example, if one takes a polished bar of mild steel $\frac{1}{4}$ in. dia. and about 3 in. long, and a similar bar of graphite, and immerse them to half their length, $1\frac{1}{2}$ in. apart, in sea water at 12° C., a current is generated rising up to 0·8 volts, 0·002 amperes. Considering the small size of the bars used for the test, this current is large and is responsible for accelerating corrosion of the steel which forms the negative pole of the cell. Incidentally, this test also illustrates a possible reason for failure of certain cast-iron structures, in contact with sea water due to "graphitic softening."

In this apparatus the galvanometer is the most important factor and should preferably be a combined micro-ammeter and millivoltmeter capable of measuring currents from one micro-ampere to 120 milliamperes, and pressures from 0·1 millvolt to 2·4 volts each in four ranges.

TABLE II. (Speller.)

EFFECT OF BRASS IN CONTACT WITH STEEL.

Metals.		Loss in weight, grm./sq. in./year.	Average penetration in inches per year.
Separated	Brass	0·6156	0·00448
	Steel	0·4520	0·00352
		1·0676 total	
In contact	Brass	0·0256	0·00019
	Steel	0·8752	0·00681
		0·9008 total	

Brass and steel pieces 2 by 1·25 by 0·063 in., with ground surfaces, immersed, separated and in electrical contact, in an aerated solution of 26·5 % $CaCl_2$ (refrigerating brine) for 90 days at 180° F. (82° C.).

In the author's opinion, engineers as a whole do not avail themselves of the information available particularly as regards the position of metals in the electro-chemical series. In practice it is quite common to see engineering structures made up from a combination of gunmetal, brass, steel and cast-iron. This is liable to give rise to electro-chemical action, when brass or gunmetal becomes cathodic and the ferrous metal anodic, or, in other words, the steel or cast iron is rapidly attacked. This is particularly the case when the structure has to work with sea water or brines, and Table II. indicates some results obtained by actual test. It will be observed that the corrosion rate of the steel has been approximately doubled by contact with brass, whilst the corrosion on the brass has been reduced. It should also be particularly noted that only the distribution of the corrosion is affected by the contact of dissimilar metals; the total corrosion taking place under the two conditions being essentially the same.

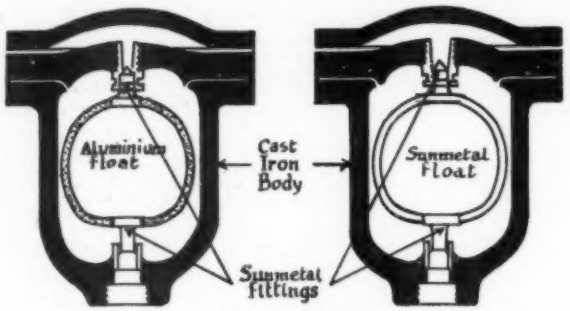


Fig. 2.—Air valve used in hydraulic engineering.

Aluminium float is liable to attack. Cast-iron body tends to be protected. *Cast iron body is liable to attack. Gunmetal float tends to be protected.*

Bringing the matter to a practical basis, Fig. 2 illustrates an example of an air valve used extensively in hydraulic engineering for the prevention of air locks in pipe-lines. These valves are often constructed from a cast-iron body surrounding a metal float operating on gunmetal seats. Generally, the float is made from a gunmetal casting, and this gives fairly satisfactory results with fresh water as the gunmetal tends to be protected from excessive corrosion at the expense of some increased corrosion on the cast-iron body. The increased corrosive attack upon the body

Fig. 3.—An aluminium door from a non-return valve which has suffered serious corrosion.

can be quite easily allowed for by the use of adequate section, and, furthermore, whilst the total corrosion may be higher, the area of the body is so much greater than the float so that corrosion is spread over a larger surface, and this is preferable to its concentration on the smaller area of the float. There have been instances, however, when

gunmetal floats proved too heavy, and aluminium was used instead. When such a combination of metals is employed it invariably results in the aluminium being extremely rapidly attacked. This can be quite easily understood when it is considered that the position of aluminium in the electro-chemical series is below that of iron, and consequently the iron will act as the more noble metal, and practically the entire forces of corrosion will be concentrated on the aluminium float to its detriment and early failure. This action is the direct reverse to that taking place when considering the use of gunmetal. Fig. 3 shows an actual example of an aluminium door from a reflux or non-return valve which has suffered serious corrosion from a cause similar to that discussed.

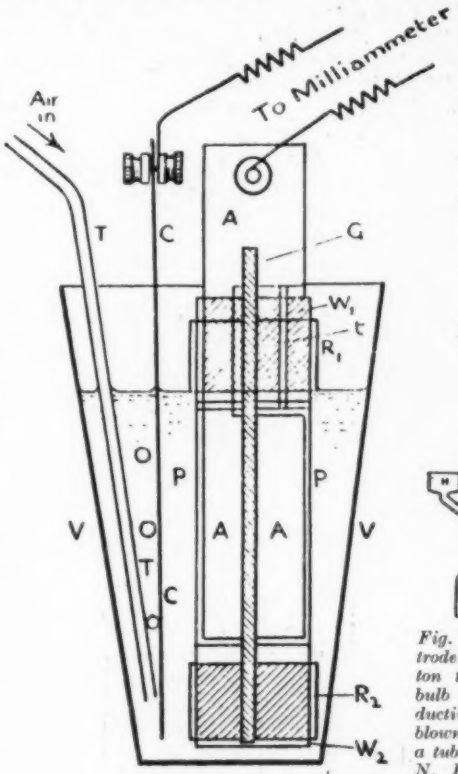


Fig. 4 (U. R. Evans).—Parchment-cell apparatus. The parchment roll P (constituting the porous partition) is wrapped round the two corks W_1 and W_2 (which are held in position by the glass rod G), and is secured by the rubber bands R_1 and R_2. The outer vessel V is of glass; the anode A and cathode C are of sheet iron. Air is bubbled in through the glass tube T.

Strips of sheet iron, C and A, are immersed in two compartments of a cell divided by a porous partition P, both compartments are filled with N/2 potassium chloride solution and the two strips are joined respectively to the terminals of a galvanometer. Air is bubbled to the outer compartment through tube T. In spite of the fact that both electrodes have the same composition and finish, a current will be set up leading to unequal corrosion of the two specimens. The unaerated electrode in this case being attacked as shown in Table III. Rust and other inert substances can exclude oxygen from the surface, and so render the underlying iron anodic to the areas which have freer access to oxygen.

Closely inter-connected with the supply of oxygen is the question of rate and nature of flow of the solution in contact with the metal. A slight increase in the rate of motion over that existing in a quiet solution produces a decided increase in the rate of corrosion. All investigators agree on this point. Fig. 4a gives the result of an investigation by Speller on the effect of velocity on the initial rate of corrosion on steel pipes carrying tap water.

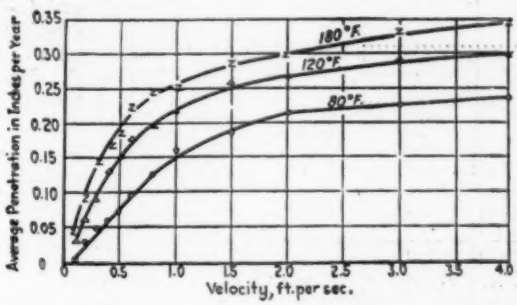


Fig. 4a.—Effect of velocity on the initial rate of corrosion in ½-inch steel pipe carrying Pittsburgh tap water.

Turbulent flow in pipe-lines and agitation of solutions in open vessels by aeration usually bring about a marked increase in the rate of corrosion. In the absence of oxygen, if the motion of the solution in contact with the metal surface is not uniform, the area subjected to the higher velocity is locally attacked, whilst when dissolved oxygen is present the reverse applies. The effect of solution motion is an extremely difficult one to study, yet it must play a most important part in many branches of engineering.

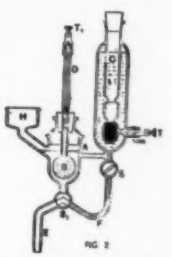


Fig. 5.—Glass electrode system (Morton type). A thin bulb B of high-conductivity glass is blown at the end of a tube D filled with N. HCl. saturated with quinhydrone, connection being made by a platinum electrode, with terminal T. The liquid under test is poured into the vessel A through the cup H, and liquid connection with the calomel electrode C is completed through stop-cocks S and S_1. The electrode is supplied ready for use, apart from the KCl solution.

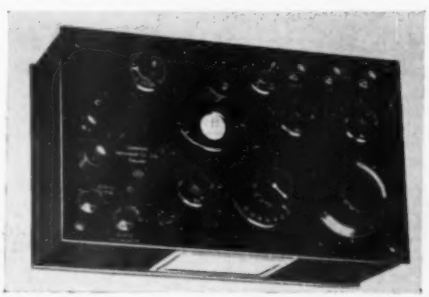


Fig. 6. — The Cambridge pH meter used in conjunction with the glass electrode shown in Fig. 6.

These few remarks serve to indicate the utmost importance of ensuring the use of proper metallic combinations in preventing corrosion. The use of dissimilar metals should not be permitted if corrosive conditions are at all severe.

Iron oxide on steel acts similarly to a dissimilar metal, and it is also possible that certain paints may act in a like way particularly if the paint has been subjected to pressure, as on rollers, etc., when the coating has become compacted and partially removed.

It must not be supposed that electro-chemical action is dependent upon the presence of dissimilar metals alone. Oxygen is capable of taking the place of a metal and an electric current can be generated between two similar metals if the supply of oxygen is greater for one than for the other. The principle of corrosion in this direction is one known as that of differential aeration, and it can be demonstrated by Evans' apparatus as shown in Fig. 4.

Now we come to the nature and composition of the corroding liquid itself. In recent years science has found that there is an important relation between metallic corrosion and the hydrogen ion concentration of *p*H value of industrial and natural waters. The fundamental ionic definition of an acid is a compound which produces hydrogen ions, electrified atoms or groups of atoms, which when in solution in water have the property of being replaced by a metal. The *p*H value is the measure of that part of the total acid present which is ionized, and is an indication of acidity or of alkalinity. The range of values adopted is from one to 14, with seven as the neutral point. Thus if a liquid has a *p*H value of one it is acid, whilst neutral liquids, such as pure water range around seven, those above seven having an alkaline reaction. The author uses and recommends the glass electrode system as being the most convenient method for corrosion testing purposes, and this is illustrated in Figs. 5 and 6. This apparatus is quite simple to use, and are rapidly operated by unskilled workers.

Table 4 indicates typical hydrogen ion concentration values of natural waters. Much work has been done

especially in America, in correlating the destructive qualities of water with the *p*H value. A convenient classification of waters originally proposed by Wilson and developed by Speller being as follows:

1. Acid waters, having a value below 4·3, which corrode iron and steel rapidly, even in the absence of oxygen, with the evolution of hydrogen gas.
2. Nearly neutral waters, having a value between 4·3 and 10, which cause rusting in the presence of oxygen.
3. Alkaline waters, with value over 10 which usually have only a very slow action on iron and steel, but may cause accelerated attack of non-ferrous metals.

TABLE III. (U. R. Evans.)

THE EFFECT OF OXYGEN CONCENTRATION CELLS.

Total current produced	22·4	milliampere-hours.
Theoretical weight of iron lost due to current	23·2	milligrams.
Actual loss of unaerated electrode (anode)	24·8	"
Actual loss of aerated electrode (cathode)	9·0	"
Total observed corrosion loss	33·8	"

Pieces of steel, aerated electrode 3 by 7 centimetres, unaerated electrode 3·9 6·4 centimetres, immersed in 0·5 *N* potassium chloride solution at room temperature for 4·5 hours.

TABLE IV. (Britton.)

*p*H OF NATURAL WATERS.

Source.	*p*H.	Notes.
Lake Kawah Idyen, Java, a crater lake in Het Idyen Plateau	1·5	Acidity due to sulphur acids.
Water in black peat	4	A little non-volatile acid.
Water in brown moorland peat	4·5	Acid largely CO_2.
Rain in open country	5·9	
Moorland stream (Dartmoor)	6·4	Value increases after each waterfall, as CO_2 is lost to air.
Springs in calcareous regions	6·0–6·6	Varying with relative proportions of calcium bicarbonate and free CO_2.
River water, non-calcareous	6·5–7·0	Also similar lakes.
River water, calcareous	8·0–8·4	Also similar lakes.
Small ponds, among weeds	9·6	During active photosynthesis.
Sea water, surface	8·1–8·4	High values in the tropics.
Sea water in pools	8·6	During active photosynthesis.
Sea water, 2,000 m., Atlantic Ocean	7·95	
Sea water, 1,000 m., Black Sea	7·26	H_2S below 180 m.
Water in alkali soil, Sudan	10·0	Sodium carbonate present.

It is interesting to note that the *p*H values of sea water are invariably higher than most other natural waters, and therefore sea water should actually corrode iron and steel structures less. Table 5 gives some results obtained on various metals and alloys when immersed in Kilmarnock tap water and Troon sea water. It will be observed that cast iron, mild steel and zinc do actually under certain conditions suffer less deterioration in sea water, but other alloys, particularly those in the non-ferrous group, have a greater loss. Probably the most reliable way of utilising the hydrogen ion concentration value in connection with the corrosive powers of various waters is to consider it in conjunction with the concentration of chlorides, oxygen and free carbon di-oxide present. It might also be of interest to mention that in connection with galvanised vessels and pipes corrosive action is at a minimum at *p*H 9·5 to 10·0.

Temperature has usually, on the whole, an accelerating effect on corrosion, and consequently must be taken into careful account, particularly in all research work.

TABLE V.

Metal.	Loss in grammes per square metre per 24 hours in aerated solutions at 60° F. for 600 hours in :—	
	Kilmarnock tap water. *p*H value 7·35 to 7·65.	Troon sea water *p*H value 8·24 to 8·33.
Cast iron	7·5	3·5
Mild steel	10·5	4·1
Austenitic cast iron	1·2	2·5
Stainless steel (12% Cr.)	0·01	2·6
Staybrite steel	No loss	No loss
30% Chrome iron alloy	No loss	1·9
Gunmetal	0·14	1·23
Cast brass	0·20	0·70
Phosphor bronze	0·08	1·20
Manganese bronze	0·27	1·20
Copper	0·18	0·70
Lead	2·20	4·1
Tin	0·15	1·4
Zinc	2·8	2·0

The last factor to be discussed is the question of stray currents. The corrosion of buried metalwork due to this cause is often very serious. It is not confined to pipes, but occasions the G.P.O. considerable trouble by deteriorating lead-sheathed telephone cables. Stray current leaks from land generating stations undoubtedly represents a common source of corrosion, particularly if the station is handling tidal estuary water for condenser cooling purposes. One investigator even attributes much of the trouble experienced in marine condensers to this cause, but it is doubtful if this is actually the case. On the other hand, Evans, an authority on corrosion in this country, states that he has known of instances where stray currents have caused considerable damage to the hulls of ships lying in dock. Stray direct currents are possibly much more dangerous than those derived from an alternating source. Certainly electrically-driven machinery is so universal to-day that any slight current leakage is most disconcerting to the study of corrosion, and to make matters worse little investigation has as yet been conducted. Possibly this is due, in some measure, to the fact that this aspect is inclined to be outside technical

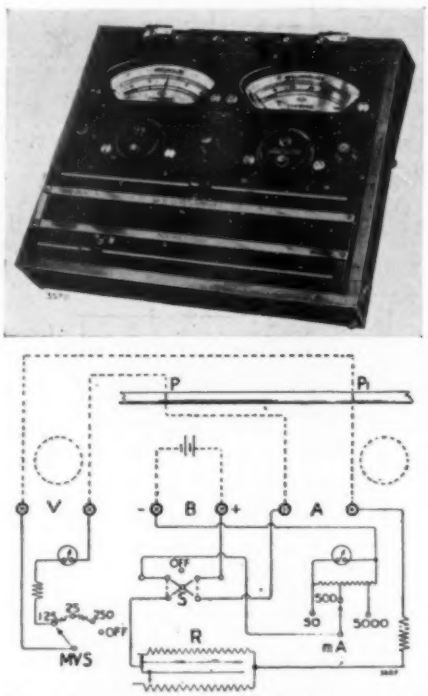


Fig. 7.—An apparatus, specially designed by the Cambridge Instrument Co., for measuring slight current leakage.

control, and comes more into the realm of practical engineering. Furthermore, in the past there has been a lack of proper apparatus for measuring these small stray currents, but this has now been fortunately corrected. The instrument shown in Fig. 7 has been designed expressly for the purpose by the Cambridge Instrument Co. Ltd., in conjunction with the British Post Office, and has been adopted by that department for measuring stray currents which cause electrolytic action and increased corrosion. This testing set is quite simple to operate and should be commended to all interested in corrosion problems, particularly as a practical means of testing an actual structure in service. The apparatus comprises a millivoltmeter, a milliammeter, an adjustable resistance and a battery. A diagram of connections is reproduced.

Two points, P and P_1, selected as far apart as possible on the structure under test are connected to the terminals V and A. The millivoltmeter is connected in parallel with the milliammeter, battery and rheostat. The potential drop across the structure under test is balanced by varying the resistance in the battery circuit until no deflection is indicated on the millivoltmeter. The reading of the milliammeter then shows the amount of current passing.

(To be continued.)

Institute of British Foundrymen

Annual Conference at Derby

A summary is given of the proceedings at this conference; particular attention is directed to the subject of the President's Address and to the various subjects discussed at the technical sessions.

THE thirty-fourth Annual Convention of the Institute of British Foundrymen, recently held at Derby, proved to be one of the most enthusiastic yet held by this Institute. Probably the central position occupied by Derby had something to do with the large attendance of members, on the other hand, the excellent programme arranged by the East Midlands Branch contributed in no small measure, and the respective committees are to be congratulated on the efficient way in which the arrangements were carried out.

The annual report of the Council was presented at the general meeting on the night of June 8 under the presidency of Mr. H. Winterton. It is noteworthy that the number of members of the Institute at the end of April was 2,065, which constitutes a record, the previous highest number being 1919, recorded five years ago. The present figure shows a net increase of 173 in the past year and may be regarded as a healthy sign. At this meeting Mr. C. W. Bigg was formally elected president, on the proposition of Mr. Winterton, while Mr. J. Hepworth, J.P., M.P., and Mr. W. B. Lake, J.P., were elected vice-presidents; other officers elected included Mr. S. H. Russell as treasurer. It is noteworthy that Lord Austin of Longbridge, K.B.E., has been elected an honorary member of the Institute. Various awards were announced at this meeting, including that of the Oliver Stubbs medal and the first award of the E. J. Fox Medal, to Mr. P. A. Russell and Professor Thomas Turner respectively.

Following the business meeting, members and their friends were given a civic reception by the Mayor of Derby (Councillor Mrs. Petty) at Bemrose School. Members of the Town Council, Corporation and public officials and other responsible townspeople were also present. An interesting social programme which followed the reception was much appreciated.

The Conference opened on the morning of June 9 at the Guildhall with addresses of welcome by the Mayor of Derby, the President of Derby Chamber of Commerce (Mr. Cecil Murray) and Mr. W. A. Richardson, O.B.E., Principal of Derby Technical College. Mr. P. A. Russell received his award of the Oliver Stubbs Medal, the Mayor making the presentation, while the presentation of the E. J. Fox Gold Medal was made by Mr. E. J. Fox. Since this is the first time this latter medal has been presented, a brief reference is made to it here.

E. J. Fox Gold Medal

At the last Annual General Meeting the retiring president, Mr. J. E. Hurst, announced that Mr. E. J. Fox, Managing Director of the Stanton Ironworks Co., Ltd., had presented the sum of £500 for the establishment of a Gold Medal to commemorate the development of the centrifugal casting process in this country. The medal was to be presented to the individual who had contributed in some outstanding way to the progress of the foundry industry, with particular reference to foundry metallurgy. Mr. Fox considered that the active association of Mr. Hurst with the development of the centrifugal casting process was a fitting opportunity to make this gift.

By courtesy of Mr. J. S. G. Primrose.

Messrs. W. B. Lake, J.P., C. W. Bigg, and J. Hepworth, J.P., M.P., respectively Junior Vice-President, President, and Senior Vice-President of the Institute of British Foundrymen.

The medal is awarded by the Council on the recommendation of two assessors, whose decision as to the suitable candidate might be made in collaboration with the president of the Institute. Sir W. J. Larke, K.B.E. and Sir Harold Carpenter, F.R.S., accepted the invitation to act as assessors for a period of three years. On their recommendation the Council decided to make the first award of the medal to emeritus Professor Thomas Turner, M.Sc., largely for his early work on the influence of silicon in cast iron which was published over 50 years ago. In this one thing metallurgists of every nation are in agreement, that the explanation and understanding of the influence of silicon on the constitution and properties of cast iron disclosed by the investigations of Thomas Turner laid the foundations of cast iron metallurgy and scientific ironfounding. In 1888 the influence of sulphur in foundry iron occupied his attention, and some of his investigations are to be found in a paper read before the Iron and Steel Institute during that year. His systematic investigations into the volume changes which occur during the solidification of cast iron were extended to other non-ferrous alloys. These were made possible by the invention of a form of extensometer, and the numerous papers by himself and his students embodying their experiments with this instrument are to be found in the Journals of the Iron and Steel Institute and the Institute of Metals over the early years of this century (*e.g.*, J.I.S.I, Vol. I, 1906. Hague and Turner and H. I. Coe, J.I.S.I., 1910). His attention was devoted also to the properties of metals, and he may be regarded as one of the early pioneers in the scientific study of the property of hardness in metals. He devised a form of scratch hardness testing instrument, known as the Turner Sclerometer, described

as early as 1886 in the "Proceedings of the Birmingham Philosophical Society," Vol. 5, page 291, and later in the Journal of the Iron and Steel Institute, Vol. 1, 1909.

It is impossible to recapitulate the nature of all the work of Professor Turner during his long and active association with the science of metallurgy. In spite of all his many activities, however, his work on the influence of silicon in cast iron will ever be regarded as his greatest contribution to the knowledge of the metallurgy of cast iron. This work was carried out before Sorby's paper on the application of the microscope to iron and steel was written, and before the methods of high temperature devised by Le Chatelier had become known to the metallurgist. The work was part of a deliberate plan to determine, by synthetic methods, the factors governing the properties of cast iron with a view to permitting their scientific control. This plan, in Professor Turner's own words, arose out of the suggestions of Dr. Percy, Sir W. Roberts-Austin, Sir Robert Hadfield, F. W. Harbord and other metallurgists of that time whose names shine forth in metallurgical history and with whom Professor Turner is a living link. How far it has been successful cannot be better judged than by ourselves who are familiar with modern metallurgy of cast iron. Foundrymen throughout the world will share with him the immense pride in contemplating the more recent developments in the metallurgy of cast iron, of which he laid the foundation stone. No more worthy person could have been chosen to be the first recipient of this medal and this was emphasised by Mr. Fox in making the presentation.

Foundry Executive

After the induction of the new president to the chair, Mr. Bigg delivered his inaugural address in which he raised and answered important questions regarding the status of foundrymen and the difficulties of attracting the best type of personnel. In his opening remarks, Mr. Bigg asked: Does our industry receive from the community in general, tangible recognition. Recognition commensurate with its contribution to, and importance in, the general scheme of things?

One of the most urgent problems with which we are concerned, said Mr. Bigg, is the recruitment of personnel. By personnel he meant not only the heads of departments, but the whole body of recruits for the different sections of the whole of our industry, which must contain the material from which the heads of departments are made. Unless the right type of recruits are obtained the foundry can never expect to have directing the industry men who will keep it in a position worthy of its importance . . . What are our chances of getting such men?

Is the industry, in any of its branches, attracting to its ranks, in any numbers, the type of man indicated as necessary? One's own experience, the opinions generally expressed when foundrymen foregather, are all eloquent of the fact that we are not . . . Lord Austin said he had never been able to understand why the foundry had always been the "Cinderella." Can we expect ambitious young men to be attracted to an industry which carries such a label? There is plenty of evidence that this is one of our industry's main problems, and we, as an Institute, have to face it. If this reasoning is correct, then we must aim at less arduous toil in more attractive surroundings, by improving the construction and layout of our foundry buildings and by the introduction of a more accentuated rate over the present one of methods and plant for the elimination of the heavier tasks attached to the production of castings. As an industry we must be prepared to negotiate on competitive monetary terms for men capable of filling responsible posts. Mr. Bigg contends that it is largely a reflection on the general conditions in our industry, and that a satisfactory supply of recruits can only be expected as a parallel of a decided improvement in those general conditions. He suggests that the problems of foundry personnel and foundry status are closely connected. Improve the one, and you will improve the other, but we shall not attract to the foundry industry the type of man required, nor shall we improve the status of the industry, unless and until we improve the general conditions of the industry,—everything that goes to make up the life of a foundryman,—and it was in this connection that he asked the question, "For what the foundryman does, what does the foundryman get?"

Does our industry in general, asked Mr. Bigg, consist of foundries that are well organised, well equipped and well run? A question he answered in the negative. He holds the opinion that in the foundry industry as a whole, as well as in individual foundries, organisation is not very strongly in evidence. The greatest protection for our or any industry is efficiency, and it is this, rather than price maintenance, which should be the object of trade associations. We should realise the value of any factor contributing to the conservation of effort. The analytical mind should not be confined to the laboratory. There is a tremendous field in our foundries for the analysis and the systematising of effort. Any effort which by proper organisation could be avoided is waste effort, and he ventured the opinion that waste effort costs our industry more than waste castings.

Following this plea for developments in management and equipment, as contributing to better conditions and prospects, leading ultimately to improved personnel and status, Mr. Bigg said, we have continued to make tremendous contributions to the well-being and progress of mankind, and, as an important constituent of that larger organism, the community, we have a right to claim a return for our services. The remuneration of our industry is the governing factor in its standard of working conditions and life for all engaged in it. There can be no such development or improvement unless the return for our products, at its minimum, is equal to the efficient cost of those products. Anything less is detrimental to the industry and those engaged in it, and it is eventually detrimental to the community. He emphasised that his argument was not for increased prices. He claimed that a well organised, well equipped, well run foundry industry will result ultimately in the lowering of the cost of its services to the community, but such an industry will also have the knowledge and power to take some part in the assessment of the value of its products, and this led to the question: Has the foundry industry in general the knowledge necessary to assess the value of its products?

He did not hesitate to reply in the negative, and he was equally emphatic in stating that to this particular weakness in the industry's structure could be attributed many of the disabilities which foundrymen consider to be their portion. It is because of this that he holds the view that in bringing the subject of costing to the fore, the Institute is doing a very real and necessary service to the industry.

Costing is as integral a part of the foundry industry as is the laboratory, and there exists no more important adjunct to organised management than a good costing system. Its value as a dimensional factor in the works, as distinct from the office, cannot be exaggerated.

Mr. Bigg spoke of the remarkable developments which have taken place on the technical side of the industry during the 34 years during which the Institute has existed. He stated that knowledge of materials has been extended to almost indescribable limits, whilst the quality and scope of foundry products is evidenced by the demands made upon British foundries. He concluded by saying that there is not a section of industry to which by our products we do not make considerable contributions. Yet in spite of all this, among the foundry's chief problems are its lack of recruits and its lowly status.

In his remarks he endeavoured to point to improved conditions resulting from a higher level of organised efficiency as a possible solution. The past, present and potential demand for castings combined with the mental and physical efforts necessary for their production form the fundamental basis of the foundry industry's importance.

With foundrymen lies the responsibility that its general organisation and efficiency is such as to produce conditions attractive to the best brains available and to ensure that the status of the foundry is among the highest in industry.

Technical Sessions

As usually occurs at their annual conference, however well intentioned the efforts to adhere to schedule, the time of the technical sessions is encroached upon, and this occasion was no exception, causing undue haste in the presentation of the third "Edward Williams" Lecture, which was given by C. H. Desch, D.Sc., Ph.D., F.R.S., and in dealing with a paper giving recommendations concerning the establishment of costs in a grey-iron foundry, by the Costing Sub-committee of the Technical Committee. On the following morning, in addition to several papers of wide interest on the ferrous side of the foundry industry, a non-ferrous symposium was presented which included both French and German exchange papers. The main features of the papers presented are given in the following summaries.

NOTES ON THE STRUCTURE AND CHARACTERISTICS OF ALUMINIUM ALLOYS

Some of the properties of aluminium alloys are discussed in a paper by Mr. H. C. Hall, in which the author surveys present knowledge, with particular reference to structure, life, and physical strength. The grain size of metals and alloys of a particular composition and cast under particular conditions is extraordinarily constant, as is indicated by fracture and micro examination. This may be partly due to characteristic grouping just prior to, and during solidification. Also, it appears that when there is a considerable solid solution of one metal in another the greater affinity between them results in either a greater number of crystals in a given volume, or marked dendritic tendency due to more gradual solidification. The latter is also observed when a pure metal solidifies in the presence of a considerable proportion of a constituent of much lower melting point.

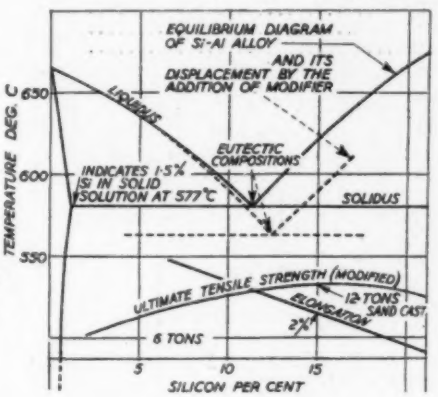
In the case of aluminium, the macro structure is not much affected by eutectics or compounds which largely make up the cell walls of the micro structure. If an alloy of aluminium containing only a small amount of metal capable of being retained in solid solution is rapidly cooled from a temperature considerably above its melting point, very large macro crystals are generally observed. Slower cooling as the result of casting in a sand mould generally promotes crystallisation from numerous centres without the development of sufficient energy in a given time to permit an extended orderly arrangement.

The strength of the structure depends both on cohesion between the constituent crystals at the cell walls and also on the cohesion at crystal cleavage planes, etc., inside. On deforming a ductile metal, slip takes place along these planes, but cell-wall accommodation is also necessary for change of shape without fracture. Thus, brittle cell walls, due to the ejection of impurities or metallic compounds during solidification and cooling in the mould, may, even in very small quantity, have a great effect on ductility.

Resistance to fatigue is different, since breaking may occur without any measurable plastic deformation. It has been proved, however, that at the region of stress concentration, the material should, for reliable service under most conditions, be capable of accommodation, accompanied by an increase in hardness without crack development. This tends to shift the locality of stress concentration to adjacent parts. At the same time, its magnitude is automatically reduced owing to its distribution over a larger volume of material.

Modified Alloys

Common unavoidable impurities in aluminium are silicon and iron. The former, if below 0·3% may be in a so-called solid solution in the aluminium, and is then invisible under the microscope. About 20% of silicon can be dissolved in molten aluminium at about 800° C., on cooling to room temperature, however, it is largely thrown out again. The silicon-aluminium equilibrium diagram, shown in the accompanying illustration, shows that the eutectic composition is 12% silicon, solidifying at 576° C. The dotted lines show the under-cooling effect of modification by traces of sodium. Rapid cooling produces a similar effect to the sodium addition, as it increases both tensile strength and the ductility. The curves in the lower part give an approximate idea of the change in ultimate strength and ductility with increase in silicon. This is a modified alloy cast in sand.



Si-Al equilibrium diagram, and the effect of Si on the physical properties of a sand-cast modified alloy.

Modification appears to alter the solubility of silicon in aluminium, tending to retard their separation on cooling. The fact that casting from a very high temperature, say, 950° C., into a chill mould produces a finer grain structure than casting from about 700° C. in the same mould, suggests that separation or grouping of the silicon and aluminium takes place above the apparent solidifying temperature. This is confirmed by soaking a molten eutectic alloy at about 600° C. in the crucible without stirring, when it is found that the lighter constituent, silicon, tends to rise. For similar reasons, a copper-aluminium alloy with about 12% copper, treated in the same way, may have twice as much copper at the bottom of a pot after standing. Zinc behaves in a similar way. It is noteworthy in this connection that induction-electric melting tends to maintain uniformity of composition by the stirring effect which tends to set up eddy currents.

Alloying Elements

Copper was probably the most important constituent of aluminium alloys used in the past, and with more than 3% of copper, whether chill or sand cast, there is a cellular structure, in which the copper-aluminium compound $CuAl_2$—a very brittle constituent—comprises the network. With the common 8% copper alloy, sand cast, there is about 12% of this compound by volume, which reduces the ductility considerably on the tensile test.

Efforts to eliminate the cellular formation of copper-aluminium eutectic, particularly in sand castings with about 8% copper, and thus to increase the ductility, have not been very successful, though 1·0% iron and about 0·25% titanium are beneficial. Beryllium and lithium also have a similar influence.

Another important constituent of aluminium alloys is the compound magnesium silicide, Mg_2Si. Since silicon is always present in commercial aluminium and has a strong affinity for magnesium, it follows that Mg_2Si is always present when magnesium is added to aluminium. This compound, together with the copper-aluminium compound, are the two most important constituents of aluminium alloys from the heat-treatment point of view, and both go into solid solution in aluminium containing them, if heated at about 500° C. for a suitable period—*i.e.*, about half an hour for chill-cast alloy, and at least three

hours for a sand-cast alloy. The relative solubility of various constituents of aluminium alloys at ordinary temperature and at about 500° C. is given in Table I.

TABLE I.

SOLID SOLUBILITY OF VARIOUS ELEMENTS IN ALUMINIUM.

Constituent.	Temperatures. 10 to 30° C. % by Weight.	490 to 510° C. % by Weight.
Copper	0·25	4·1
Magnesium	1·30	12·0
Silicon	0·20	1·1
Magnesium silicide	0·45	1·4
Manganese	0·20	1·0
Lithium	2·40	2·8
Silver	1·5	40·0
Cadmium	0·05	0·8
Zinc	3·2	42·0

Quenching from the solution temperature traps a large proportion of the $CuAl_2$ and Mg_2Si or Si in the solid solution state. If more than one is present mutual effect on individual solubility in the aluminium is observed, as would be expected. Other constituents also complicate the behaviour of aluminium alloys, so that phase and equilibrium investigation may be very difficult when, for instance, iron about 1·0% is present. The compound $MgZn_2$ behaves similarly to Mg_2Si, although its solution temperature is lower—*i.e.*, about 450° C., and its optimum ageing temperature about 100° C.

Hardness and Strength of Development

Solution treatment is carried out in order to develop maximum hardness and strength, but this result is not fully achieved without subsequent ageing or precipitation treatment. This latter may be practically complete by storage at normal air temperature for a week or so. Cast alloys, however, as a rule, require artificial heat—*i.e.*, heating to about 150° C. for 12 hours, the hardness thereby increasing from about 75 in the solution-treated condition to as much as 150 Brinell.

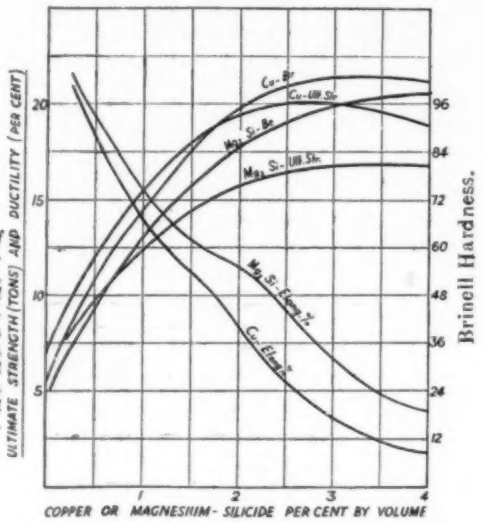
From tests it can be shown that with about 2·0% Cu or Mg_2Si by volume there is, as previously suggested, a maximum effect due to heat-treatment when about 50 volumes of aluminium are associated with one unit of these compounds. If more compound than this proportion is present, hardness is not increased in proportion, but ductility decreases markedly owing to the excess $CuAl_2$ or Mg_2Si being deposited at cell walls, these taking little part in the changes during solution and ageing treatments. The accompanying illustration shows at volume percentages the hardness and ductility variation and maxima obtained by complete heat-treatment with an increase in copper and magnesium silicide.

Heat-treatment

Heat-treatment does not result in serious volume dimensional changes so long as precaution is taken to avoid distortion at the moment of actual quenching from the "solution" temperature. On the other hand, heat conductivity is considerably reduced by it as compared with the alloy in the "as cast" or "annealed" condition.

Quenching a large casting which has considerable local variation in section results in local internal stress. Subsequent normal ageing treatment does not tend to reduce this, and may even aggravate it, owing to the simultaneous increase in hardness which occurs. Such stress may approach the elastic limit of the material and cause the casting to fail under relatively light loading in service. A semi-anneal treatment with some consequent sacrifice in Brinell hardness and elastic limit, may be beneficial in such a case.

Castings are often given an ageing or precipitating treatment only at about 150° C., primarily to prevent future distortion. Some increase in hardness and reduction in ductility is noted as a rule. This is more marked with chill-cast alloys in which more $CuAl_2$ and Mg_2Si, etc., are retained in solid solution owing to relatively rapid cooling in the mould; this is equivalent to a mild solution treatment. After about 6 hours at 150° to 170° C. internal stresses due to casting contraction are generally eliminated completely if the material is not solution-treated. The alloy RR50 is treated in this way, since the gain in strength



Variations of ultimate tensile strength, ductility and Brinell hardness, with an increase in copper and magnesium silicide (chill cast and heat-treated.

obtained by the duplex treatment is not sufficient to warrant the added cost. With higher Mg_2Si, however, as present in RR53C, or extra copper, a considerable increase in ultimate stress results. Both treatments improve machinability. A comparison between RR50, RR53C, and RR53 fully heat-treated and also precipitation-treated is given in Table II.

TABLE II.

COMPOSITIONS AND MECHANICAL STRENGTH (TENSILE AND HARDNESS).

	Cu.	Ni.	Mg.	Fe.	Si.	Ti.
RR50	1·3	1·1	0·12	1·1	2·30	0·18
RR53C	1·2	1·3	0·50	1·1	2·50	0·16
RR53	2·1	1·3	1·50	1·1	1·0	0·07

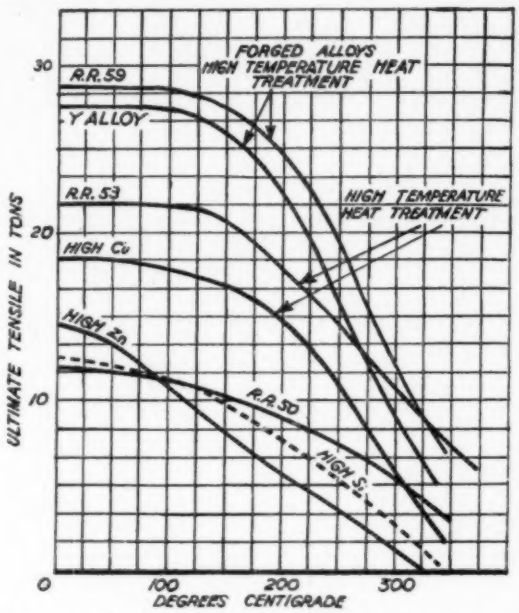
—	Low-temperature Heat-treatment (160° C. for 8 hours). Proof Stress.	M.S.	E. %	Br. H.
RR50 sand cast	9·0	12	3·0	70
RR53C sand cast	9·5	14	2·0	77
RR53 chill cast	12·5	17	1·0	96

—	High-temperature Duplex Treatment (520° solution treatment then 160° C. for 8 hours). Proof Stress.	M.S.	E. %	Br. H.
RR50 sand cast	13	17	2·5	90
RR53C sand cast	19	21	2·0	103
RR53 chill cast	21	22·5	1·0	140

These alloys, like those of the rest of the series, are characterised by fineness of grain, partly owing to a carefully balanced composition and partly due to the presence of titanium, which is now generally acknowledged to have a great refining effect. Their utility is particularly in the field of heavily stressed engine parts. The tensile strength curves for RR50, RR53, and Y-alloy, compared with

several other alloys up to 350° C., are given in the accompanying illustration. The Y-alloy test is made on forged heat-treated alloy, RR53 chill-cast and heat-treated.

Aluminium containing 8 to 12% copper is liable to be too ductile at about 300° C. If other constituents are



Tensile strength curves for RR50, RR53 and Y Alloy and other alloys compared.

added, such as manganese, magnesium, or silicon, particularly when used for sand castings, in an attempt to correct this fault, the characteristic brittleness of these alloys in the cold is further increased, or heat conductivity may be considerably reduced, as is the case with manganese addition.

High Magnesium Alloys

High magnesium alloys are also very sensitive to other additions, and are not sufficiently resistant to heat for most engine parts. Cast alloys containing about 4% magnesium, together with relatively small additions of other metals, for refining or hardening purposes, though much superior in the forged condition to other forging alloys, are not so in the sand-cast condition when considering original and final physical properties after exposure to air, water and saline spray.

High zinc alloys are too susceptible to heat for use if the temperature in service exceeds about 90° C., owing to their tendency to soften with moderate heat. This softening persists on cooling, but after a time a type of ageing at ordinary atmospheric temperature results in the Brinell hardness rising from about 57 to as much as 100. It appears that this cycle of change which takes place each time the engine is run and cooled again often results in local cracking after comparatively short service. With time, the ductility is almost completely lost, even if the part is in store.

Nickel, when alloyed with aluminium, is more finely dispersed than other metals of high melting point. Iron comes next in order, and these two metals form with silicon and aluminium, complex eutectics which are not liable to coarse segregation if not more than about 1–5% of either is present; the same holds good if their total does not exceed about 2·5%. Nickel also associates well with copper in aluminium alloys, a triple eutectic being produced.

Other heavy metals of high melting temperature should only be present to a small extent since they tend to result in segregation. Consequently uniformity of melt composition is difficult with more than about 0·3% total of chromium, vanadium, molybdenum and tungsten, etc. Manganese, owing to its greater solubility, may be used in quantity, but it is liable to result in brittleness.

In conclusion, the author discusses castability and fluidity, factors of vital importance in casting alloys, and describes three testing outfits. Fluidity, he states, is much influenced by the presence of suspended oxide. Pure aluminium is not liable to contain it. In alloys, such oxide is often associated with the occluded gas bubbles in regions high in dissolved hydrogen, carbides of hydrogen, and carbon monoxide, owing to contamination by furnace gases or moisture. The efficiency of flux depends mainly on its liability to coagulate such dispersed oxide. The action is generally stimulated by the production of chloride from chlorides in the flux which produce hydrochloric acid gas with the hydrogen in the metal. This gas, being insoluble, rises with the oxide to the surface. The evolution of nitrogen or fluorine from a flux may also be beneficial, and the gas itself in the former case may be bubbled through the alloy for stirring purposes, either in the furnace or ladle.

The addition of traces of alkali metal may modify surface tension, and such additions as chlorides or flourides may be added shortly before casting, to increase the fluidity. Opalescent tints on the exposed surfaces of runners and risers indicate the presence of dissolved alkali metal, and, when these are noted, pinholing is very unlikedly to be observed in the casting concerned.

THE PROBLEM OF THE ELIMINATION OF GASEOUS IMPURITIES FROM ALUMINIUM

In the course of the last two years a new method for the degasification of metals has been perfected in the Institute of Applied Chemistry at Lille, by means of which it is possible, in particular, to effect the complete determination of the gases of aluminium.[1, 2] It was therefore considered that it would be possible to attack with new and more powerful means the problem of gases in aluminium and this is presented in the French exchange paper by Professor Georges Chaudron.

Actually the foundry industry can procure aluminium of a very high degree of purity, but it must be pointed out that neither the hydrides, the carbonyls, nor even the nitrides are determined. In many foundry operations, however, gases may give rise to blowholes which render the castings useless. It is a well-known fact that these gases are chiefly liberated at the moment of solidification, and it has rightly been said that in many cases it may be quite deceptive to have a purity corresponding to 99·99 per cent. if the last hundredth part consisted of gases. In this paper the author discusses the problem of gaseous impurities in parts: the value of the usual methods for the degasification of aluminium, and the conditions enabling this metal to be remelted without recharging it with gases.

Results are summarised from the simple methods used, namely, those in which an inert gas is bubbled through the liquid metal, and the methods in which the liquid metal is stirred without fluxes. None of these methods produces a metal freed from gases, but there is obviously an appreciable reduction in the contents. Practice has shown, however, that metals thus treated and therefore only partially degasified have given every satisfaction.

The method of extracting gases enclosed in the metal developed by the author is the bombardment in a discharge tube where the projectiles are ions and electrons. The sample to be degassed is made the cathode in a discharge tube. A bulb of rather large diameter and of very definite dimensions was selected. This bulb is connected to a

1 L. Moreau, G. Chaudron, A. Portevin: "Sur une Nouvelle Méthode d'Extraction des Gaz dans les Métaux" (On a New Method of Extracting Gases from Metals), *Comptes Rendus*, 201, 212, 1935.

2 A. Portevin, G. Chaudron, L. Moreau: Nouvelle methode pour Extraire les Gaz des Métaux et Contributions à l'Etude des Gaz Retenus dans l'Aluminium" (New Method of Extracting Gases from Metals and Contribution to the Study of the Gases Retained in Aluminium). Anniversary Volume of the Science Reports of the Imperial University Tohoku Sendai, Japan, 1936.

mercury vapour pump which delivers into a cascade of mercury, enabling the gases removed to be collected. The electric discharge passes at a very low intensity—a few milliamperes—and at a tension which may be as high as 130,000 volts. The bombardment of the sample does not produce any appreciable rise in temperature.

The author points out that in order to effect the degasification, it is not necessary to bombard the whole surface of the sample. On the contrary, it is possible, for instance, to extract all the gases from a long length of aluminium wire by introducing a very short length into the tube, or, again, it is possible to effect the degasification of a long aluminium strip by coiling it and then placing it in the discharge tube. This method enables much greater quantities of gases to be extracted from aluminium than the amounts obtained by previous investigators in this field. The author compares the volume of gas extracted by heating *in vacuo*, by fusion *in vacuo*, and by this new method. He also compares the industrial methods of degasification and as a result of experiments discusses the influence of composition of the gaseous atmosphere and the melting temperature of the gas content and on the "Rochage" of the metal.

The experiments show that the solubility of the hydrides, carbonyls and nitrides of aluminium increases with the temperature, but that this solubility is still very high in the liquid state in the vicinity of the melting point, and even in the solid state. The sole effect of practical methods of degasification is therefore to destroy the supersaturation acquired at high temperatures. It would appear that the foundryman has nothing to fear from gases properly dissolved in the metal (that is to say, in equilibrium with the latter). The author hesitates to give advice from the practical point of view, but certain conclusions follow from these experiments :—(1) Overheating of the aluminium is the first enemy of the foundryman ; and (2) gases of combustion must not come in contact with the metal.

TRENDS IN THE NON-FERROUS FOUNDRY

In presenting the current trends of development in the non-ferrous foundry, Dr. L. B. Hunt grouped his subject under three headings, covering materials, methods and products. With regard to materials particular attention is directed to the value of improvements in the purity of such metals as copper, aluminium, zinc ; to the competition encountered in the use of the primary metals, including magnesium ; to new and improved alloys ; and to developments in the treatment and control of moulding sands.

Production methods have also been advanced in recent years and the trend towards greater precision and control is increasing in importance. This is particularly true in cleansing methods devised to reduce the contamination of melts, particularly aluminium alloys, by gases. The action of deoxidisers and fluxes is discussed and the need for further study and elucidation emphasised. The need for special running methods for certain groups of aluminium alloys is mentioned. Casting methods for ingots and billets of aluminium and copper have received much attention in the last few years and a number of improved methods have been evolved. Reference is made to the marked trend towards the application of pressure to both pouring

CHEMICAL COMPOSITIONS OF NICKEL CONTAINING ALUMINIUM CASTING ALLOYS.

Alloy.	Cu.	Ni.	Mg.	Fe.	Si.	Mn.	Ti.
"Y"	4·0	2·0	1·5	0·6*	0·6*	—	—
RR50	1·3	0·9	0·1	1·2	2·25	—	0·18
RR53	2·2	1·3	1·5	1·2	1·25	—	0·07
RR53C	1·15	0·8	0·5	1·1	2·5	—	0·16
Ceralumin "C"	2·5	1·5	0·8	1·2	1·2	—	Ce 0·15
"Lo-Ex"	0·9	2·0	1·0	—	14·0	—	—
"Birmasil Special"	0·1*	2·5–3·5	—	0·6*	10·0–13·0	0·5*	—
"P.2"	3·0–4·5	1·75–2·5	0·5*	2·0–4·0	4·0–5·0	0·5*	—

* Maximum.

MECHANICAL PROPERTIES OF NICKEL-CONTAINING CAST ALUMINIUM ALLOYS.

Alloy.	Form.	Tensile.						
		Heat-treatment.	Proof stress 0·1 per cent. Tons per sq. in.	Y.P. Tons per sq. in.	M.S. Tons per sq. in.	E. Per cent.	B.H.N.	Fatigue limit Tons per sq. in.
"Y"	Sand cast	Quenched and aged	—	—	14–16	1–3	95–105	—
"	Chill cast	Quenched and aged	—	—	18–20	3–5	100–110	± 7·1*
I.R50	Sand cast	Precipitation only	9–11	—	11–13	2–4	65–75	± 4·45†
"	Die cast	Precipitation only	11–13	—	13–16	4–6	70–80	± 5·8†
RR53	Sand cast	Complete	—	—	18·20	0·5–1·0	124–148	± 5·5†
"	Die cast	"	19–22	—	21–23	0·5–1·5	124–148	± 6·9†
RR53C.	Sand cast	"Solution" only	9–10	—	14–15	2·5–3·0	70–75	—
"	"	Complete	18–20	—	19–22	1–2	100–115	—
"	Die cast	"Solution" only	10–12	—	18–20	6–8	75–85	—
"	"	Complete	19–21	—	22·24	3–6	110–120	—
Ceralumin "C"	Sand cast	"Solution"	11–13	—	14–16	1–3	98–104	—
" "	"	Complete	18–20	—	19–20	0–1	130–140	—
" "	Chill cast	"Solution"	13–14	—	19–21	4–6	98–104	—
" "	"	Complete	21–24	—	23–27	0–1	130–140	± 8·25*
"Birmasil Special"	Sand cast	—	—	7–9	12–14	2–4	50–70	± 3·5*
"	Chill cast	—	—	8·5–10·5	16–18	3–6	70–89	± 5·3*
"Lo-Ex"	"	—	—	9·5–11·5	10–13	0–0·5	65–75	—
"	"	Complete	—	15·2–16·4	16–19	0–0·5	125–140	—
"P.2"	Pressure die cast	—	—	7·0–11·5	9·5–12·25	0·5–2·0	65–101	± 4·25*

* 20,000,000 reversals. † 40,000,000 reversals.

and solidification of non-ferrous alloys in the form of die-castings.

Brief mention is made of the improvements in the mechanical properties of non-ferrous castings which have provided the engineer with products of marked superiority to those of several years ago. Such factors as heat-treatment and grain refinement, as a result of the addition of certain elements to alloys, have contributed in a large measure to these improvements. Reference is made to work on bronzes in progress by the British Non-Ferrous Metals Research Association, and competitive methods and materials are discussed.

In conclusion the author briefly refers to what lies ahead and emphasises that to provide still sounder, stronger and more uniform castings, foundrymen will require new information on melting practice and on the properties of alloys prepared under ideal conditions, and a fresh outlook on quite a few points, particularly on pouring methods and on the purification of melts by fluxes and other methods.

THE USE OF NICKEL IN NON-FERROUS ALLOY CASTINGS

Nickel is being used to an increasing extent in the non-ferrous industry and this paper by Mr. J. O. Hitchcock reviews the position in this field, but the field is so great that much detail has been omitted and attention is directed primarily to those alloys the author considers to be of special interest from the foundry point of view : in particular bronzes and nickel-silvers.

With few exceptions, the general influence of nickel is similar, whatever the base to which it be added, and it can be broadly stated that it has the following effects :— (1) Raises the melting point ; (2) increases the strength and hardness ; (3) assists in the retention of these properties at elevated temperatures ; (4) decreases the grain size ; and (5) improves the corrosion resistance. Apart from the consideration of the intentional addition of nickel to castings, the fact that appreciable percentages of nickel are frequently present in available scrap renders it doubly important to understand its influence.

The effect of nickel on the physical properties of bronzes is marked. It is generally accepted that nickel densens bronzes, although exactly what is meant by this is not always clearly defined. It has been demonstrated, however, that whilst the true freezing-shrinkage is not modified to any important extent by the addition of nickel, this element does enable sounder castings to be produced, particularly when the pouring temperature is high. Interesting results have been obtained on the improvement by heat-treatment of the mechanical properties of nickel-tin bronzes. In the gunmetal types of bronzes up to 5 per cent. of nickel may be substituted for tin, giving an improvement in strength properties and ductility. Wear resistance is a further property which benefits from nickel additions.

Difficulties which are associated with the production of good sand castings in aluminium-bronzes have limited their application. Although the systematic attention given to the effect of nickel in tin-bronzes has not been paid to its effect in the corresponding aluminium-containing alloys, nickel is known to exert an interesting influence on the physical and mechanical properties of the alloys, and in some cases, with high nickel contents, completely to change the nature of the heat-treatment required to produce maximum strength and hardness. In castings, 7 per cent. of nickel is generally considered to be its upper limit. The alloy containing 10 per cent. aluminium and 5 per cent. nickel has been found to have excellent all-round properties, particularly from the point of view of resisting sea water corrosion.

Attention is directed to the high-tensile brasses and manganese bronzes which owe their excellent mechanical properties to small percentages of added elements, and which in certain instances include nickel. Mention is made of several compositions and of alloys like "Turbadium" and "Tungum," which contain nickel. Among the nickel-copper-zinc alloys are the nickel-silvers which are popular casting alloys and typical compositions are given, while useful information on the production of sound nickel-silver castings is also given.

The use of nickel in many further alloys is also reviewed including zinc-base alloys, tin-base alloys, aluminium alloys ; with regard to the latter two tables are given, showing the composition and properties of those commonly employed in this country. These are reproduced in the accompanying tables.

Although the main sections in this paper deal with the effect of nickel additions on commonly-used non-ferrous casting alloys, the author has been able to include a summary of various types of nickel-brass alloys, including the nickel-copper alloy "Monel," nickel-copper-tin alloys, nickel-chromium and nickel-chromium-iron alloys, and nickel-molybdenum-iron alloys.

REMELTING ALUMINIUM IN THE FOUNDRY

The remelting of aluminium necessitates the preservation of values, because it is one of the most valuable metals used in industry, and this object is accomplished more completely the more the losses are reduced in quantity and the better the quality of the original metal can be preserved or restored. Hr. H. Röhrig, discussing this subject in the German exchange paper, said that the principal objects to be achieved in remelting are : preventing loss of substance, and preserving or restoring the quality. Differences between the heavy metals and aluminium and its alloys with regard to remelting are first considered.

A factor which is also characteristic of the light metals concerns the variability of the composition of the scrap metal. During the first decades of the use of aluminium, the scrap metal substantially contained, as alloying components, either copper or zinc, or both these heavy metals together. Iron also occurred as an impurity, this being partly due to the application of inappropriate remelting conditions. With the extended use of Silumin or Alpax, silicon appeared in addition to copper and zinc. Foil constituted an important source of lead and zinc as impurities in scrap aluminium, since aluminium foil mixed with tin or lead foil is often melted. Nickel appeared in the remelted aluminium alloys, particularly after the introduction of Y-alloy and the RR-alloys, and magnesium is becoming increasingly noticeable as an impurity of scrap aluminium now that alloys of the type of Magnalium and Birmabright have gained importance. This development has occurred in the space of a few decades and is still continuing. An example of this is the scrap with an oxide film produced anodically. The rapid development of new types of alloys thus produces fluctuations in the nature of the scrap metal, while a further consequence is that the scrap metal alloys often do not correspond, even fundamentally, in their composition with the new alloys, but lag behind them.

The colour of the various kinds of scrap aluminium differs only slightly and increases the difficulty of collecting and sorting. A further difficulty is that aluminium scrap frequently has a coating of paint, which is a source of trouble during melting and favours the absorption of gases. Further, it is necessary to take into consideration that it is almost impossible to eliminate unwanted alloy components during remelting. The selection and handling of remelted aluminium would be facilitated if standardisation of the compositions were to be introduced on a wider scale.

Preventing Metallic Losses

Oxidation is the principal source of the loss of metal. The lower the melting temperature and the purer the metal, the less the oxidation. Under normal conditions, aluminium and its alloys should not be heated above from

730° C. to 750° C. It seems that certain impurities, such as sodium, calcium and even magnesium increase the tendency of aluminium to oxidation. Despite the fact that the oxygen in the furnace atmosphere contributes to oxidation of the metal, it is generally inadvisable to melt with a reducing flame, because the absorption of gas by the melt is thereby promoted. As a general rule a slightly oxidising furnace atmosphere is to be preferred. The loss of metal is mainly due not so much to direct oxidation as to the fact that the oxide films enclose particles of metal and prevent them coalescing. Suitable fluxes are employed for lubricating these enclosed droplets of metal. Cryolite possesses a high solvent action for oxide, and really useful fluxes are produced by mixing it with common salt and potassium chloride for lowering its melting point. The use of calcium chloride and zinc chloride as fluxes are also considered.

The contamination of the scrap by oil is a further cause of melting losses and scrap should be degreased before being charged in the furnace. Unsuitable melting furnaces are to be regarded as a source of loss of metal.

One of the most effective means of minimising remelting losses is the addition of virgin metal, as the metal from the electrolysis works still contains effective quantities of flux. The extent to which the casting properties of a melt may be improved by the addition of 10 to 20 per cent. of electrolytic aluminium is often surprising.

A large number of methods have been recommended for degasifying the molten baths. In Germany, the introduction of chlorine gas or chlorides has been successfully urged. These methods are more suitable for remelted aluminium, the simpler and cheaper their application, and the desired object is often attained even by stirring in a heavy metal chloride which reacts in contact with the molten aluminium. Mixtures containing organic chlorine compounds have also proved efficient. In any case, when a double treatment is necessary for de-oxidation and degasification, it is essential to carry out the degasification last. Alloys containing magnesium in particular exhibit a tendency to renewed gas absorption when they are stirred again.

WEAR TESTS ON FERROUS ALLOYS

The problem of wear in relation to certain engineering metals and alloys has been the cause of much experimental work in an effort to discover materials which offer greatest resistance to wear under working conditions. A contribution to this problem is presented in a paper by Mr. Owen W. Ellis, which describes a series of tests on sand-cast balls in a suitable abrading medium. The author, in collaboration with his colleagues, presented a paper on the wear resistance of white cast iron, about two years ago, at the Convention of the American Foundrymen's Association in Toronto, Canada. The tests described in that paper were carried out in end-discharge porcelain jars, which were charged with cylinders or balls, together with silicon carbide and water. The loaded jars were rotated in a mill, and percentage losses in weight of the balls were calculated at stated intervals. Various cast irons were tested in this way, and from the results the authors gave certain conclusions, among which was the interesting conclusion that the higher the carbon content of white cast iron, other things being equal, the lower is its wear resistance under the conditions described.

This conclusion was thought important enough to warrant further experiment, and two series of tests were carried out with 1 in. diameter sand-cast balls. The results of these tests, which are given in the present paper, fully confirm the view that (under the test conditions described) the wear resistance of white cast iron decreases as the carbon rises. Also, the impression is created that the wear resistance of steel falls with decrease of carbon. In short, maximum resistance to wear in silicon carbide obtains in alloys on the borderline between steel and white cast iron—alloys having a structure corresponding to that of the 1·7% carbon alloy of the pure iron/iron carbide system.

Much more work has since been carried out under the same test conditions, and the results have shown that many alloys of low Brinell hardness number resisted abrasion as well as, and often better than, alloys of high Brinell hardness number. Many pearlitic alloys have been found superior to martensitic alloys, and many austenitic superior to pearlitic. The outstanding feature of the tests as a whole has been the marked superiority of the alloys containing chromium. A number of abrading materials have been used in the tests, and numerous anomalies are shown which have yet to be explained.

It is clear that mineralogical hardness, *per se*, is not the only property which affects the wear of alloys of different types. The crystal structures of minerals must, of course, be considered in any discussion of their abrasive effects. It is probable that in its influence upon the wear of metals and alloys in mills, the arrangement of the atoms on the crystal lattices is as significant as the mineralogical hardness of abrasive materials. The energy absorbed in grinding a substance of high mineralogical hardness, but with gliding planes along which slip can readily proceed, may quite well be less than that absorbed in the grinding of a substance of low mineralogical hardness, but with a crystal structure more resistant to fracture by cleavage. At the moment, the relationship between crystal structure and abrasive effect cannot be defined.

Many other factors, affecting by their variation the outcome of tests in small mills, are not referred to in the paper. Nor at the present time does the author claim that the results of these small mill tests can be used to predict accurately the performance of alloys (as balls) in large mills—though a few commercial tests encourage him to hope that results of tests in small mills may serve as a rough guide to procedure on a larger scale.

THE ESTABLISHMENT OF COSTS IN GREY-IRON FOUNDRIES

The Costing Sub-Committee of the Technical Committee of the Institute detailed their recommendations in this paper concerning the establishment of costs in a grey-iron foundry. The Committee stated that it is necessary for the costing system to be based on standard principles in order that costs may be established on a comparable basis for the whole industry.

Fundamental Principles.—(A) Each job should be charged with its full costs, including its proper share of overheads; (B) the undertaking should be divided into a number of departments, in each of which the various grades of metal, types of castings, etc., should be classified; (C) all inventories and records should be kept methodically and correctly.

Divisions of the System,—There are four main divisions; (1) melting; (2) moulding; (3) core shop, and (4) cleaning and fettling, together with the following auxiliary departments: pattern shop; maintenance department; heat, light and power; despatch department, etc.

Divisions of Costs.—The costs are divided into two chief groups:—

(1) *Direct costs* are those items which can be charged specifically against a job, and include:—(*a*) *Metal*, which is charged at the actual cost of the metal going into good castings delivered. (*b*) *Moulding and Coremaking*, covering the value of moulding and coremaking labour expended in the making of moulds and cores, and when made specially for the job, moulding boxes, patterns and tackle. (*c*) *Fettling and Cleaning*, against which only direct labour is charged.

(2) *Indirect Costs* are those items which cannot be specifically charged against a job, and are an expense of the department to be allocated to the various jobs; in

the case of metal and a certain section of the fettling and cleaning department, these are charged on a tonnage basis, and other sections as a percentage on direct labour.

The object of the system, as applied to the melting department, is to arrive at the *cost of the metal at the spout per ton of good castings produced.*

The system advocated enables costs to be checked at each stage, provides for a fair allocation of costs to different types of castings, and also permits of a closer control of the working of each department.

The four main divisions of the system, which apply to any grey iron foundry, correspond to the following departments :—

I.—Melting department.
II.—Moulding department.
III.—Core department.
IV.—Cleaning and fettling department.

In addition, there are a certain number of auxiliary departments that contribute to the proper functioning of the main divisions listed above. Among the most usual auxiliary departments are :—The pattern shop ; maintenance department ; heat, light and power ; and despatch, etc.

The two tables appended below are of figures taken at random, for the purpose of illustrating the application of the system :—

COST OF METAL.
MIXTURE "A."

		£	s.	d.	
40 tons	of pig-iron (*a*) at £4 per ton	160	0	0	
20 ,,	pig-iron (*b*) at £3 10s. a ton	70	0	0	
20 ,,	bought scrap at £2 10s. a ton	50	0	0	
80 tons	average price £3 10s. per ton..	280	0	0	
40 ,,	home scrap at £3 10s. (average price)	140	0	0	
Iron melted 120 ,,	total cost of mixture	420	0	0	
35 ,,	less scrap returned at £3 10s.	122	10	0	
Iron used 85 ,,	cost of metal going into good castings.....	£297	10	0	(A)
		T.	c.	q.	
Tonnage of good castings produced (67½% of total melt)		81	0	0	(T)
Cost of metal per ton of good castings produced A/T		£3	13	6	

Metal loss (for rererence) 3.33% of total metal

COST OF MELTING AND ONCOST.

	£	s.	d.
Labour, charging, etc. (wages book).....	8	0	0
Coke, limestone (price as per inventory).....	16	0	0
Plant maintenance and repairs (labour and materials) (at cost).....	5	0	0
Ganister, supplies (price as per inventory)	4	10	0
Loose plant (at cost)	1	10	0
Supervision (pay roll).....	1	10	0
Light, power (measured or estimated)	2	10	0
Share of fixed charges (rent, rates, depreciation, etc.) allocated on floor space, etc.	3	10	0
	£42	10	0 (B)

(Iron melted, 120 tons = 7s. 1d. per ton of metal melted.)
Good castings produced, 81 tons (67½% of melt) = 10s. 6d. per ton (Class No. 2).

THE PRODUCTION OF INGOT MOULDS

It has been felt that a paper of a practical nature, showing developments in the production of ingot-mould castings would be especially significant to steelmakers and prove that progress in this phase of foundrywork is as rapid as in other branches of foundry activity. These apparently simple castings must conform to definite standards, must withstand extreme variations in temperature and heavy usage, be strong enough to undergo water spraying for cooling when exceptionally hot, and the internal finish nust be good, this having a direct bearing on the ultimate life of an ingot mould.

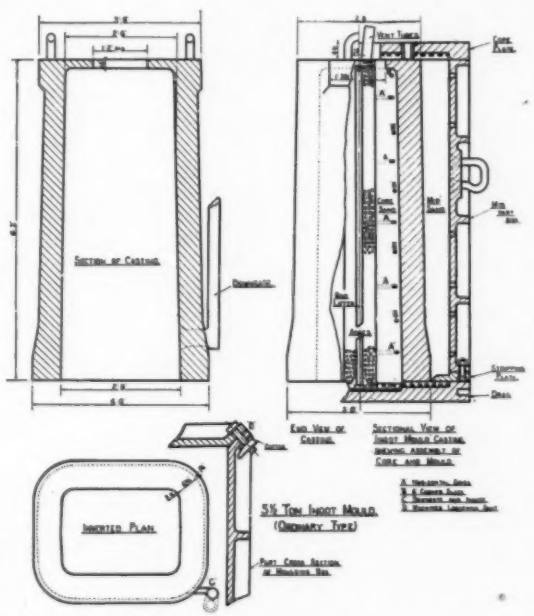
Two types of moulds are manufactured :—the common or ordinary in which the top area is smaller than the bottom, and the inverted, in which the bottom area is the smaller. The production of these castings was discussed in a paper by Mr. R. Ballantine, in which he referred to, and illustrated the production of a 5½-ton common mould, with semi-closed top and a 14-ton inverted type, among others. Designs in both cases are extremely varied, ranging from square and rectangular to fluted octagonals and duodecagonals.

Such factors as fundamentals for core production, gating and feeding, moulding boxes, analysis and usage, design of moulds, weight ratios and lives were presented in commendable detail, as the following extract shows :

"There are certain features in core manufacture for this class of work which should be noted if satisfactory castings are to be produced :—

(1) The sand must be permeable, otherwise flaking in the corners occurs in the larger moulds, due to back back pressure into the mould cavity. Ordinarily, release of gas should be through the core into the ashes, gas escaping as the metal rises. The artificial pricking of corners does not appeal as a means to assist venting or to counteract the scaling in corners. Were it convenient to do pricking from the inside of the core to the corners, then the advantages would be apparent.

(2) A liberal coating of blackwash eliminates the tendency to fuse where there are heavy metal thicknesses.



Composite sketch showing an ordinary type of 5½-ton mould.

(3) It has been proved in practice that if these cores be dried throughout, the best results are not obtained. Cores dried inside are usually overheated on the outside. Consequently a curling on the caked blackwash occurs, leaving indentions which must be levelled in the finished casting.

"It is the author's experience that cores manufactured with a minimum of handling, and a minimum of disturbance in transit, gives the best results. More trouble is caused by strains set up in the cores when in their green state, prior to entering the stoves, than is credited."

The author gives additional data and alternative methods, including stages such as ramming and jolting, hot tears, flaking or corner scaling, core expansion and design, and illustrates a number of cores and castings.

FOUNDRY AND LABORATORY CHARACTERISTICS OF CUPOLA COKES

Research work, upon which this paper by Dr. Hugh O'Neill and Mr. J. G. Pearce, is based, consisted of foundry trials using a cupola with a daily melt of about 60 tons of a uniform grade of metal (carried out at the Derby L.M.S. Locomotive Works) ; carbon and sulphur pick-up tests on the B.C.I.R.A. experimental balanced-blast cupola using known and uniform charges ; and laboratory tests of a physical, chemical and microstructural nature.

The foundry trials consisted of a day's run on a cupola engaged in the manufacture of railway chairs, the melting rate was calculated from the time of blast on to blast off with due allowance for all stoppages. The air supply was delivered by a fan running at as constant a speed as possible and any variation from normal in the supply could therefore be attributed to the coke. Analyses of cupola gases were taken each morning and afternoon, and the results averaged. CO_2 content was generally about 18·5% and oxygen less than 0·7% Test bars and test castings were taken three times daily, percentage of scrap was noted, the make of slag was weighed and its chemical analysis obtained together with that of the castings. Metal temperature at the spout was taken frequently throughout each melt by means of an " Optix " optical pyrometer.

Results of this section of the tests showed that the best coke from the thermal point of view is the one giving the highest metal temperature, provided that the melting rates of all the cokes are equal. Alternatively for a given satisfactory metal temperature the coke with the highest melting rate is thermally the best. A high melting rate tends to penalise the temperature owing to decreased time of preheating in the cupola shaft. It can otherwise be a disadvantage, and inquiry shows that economy generally results from cokes giving high temperatures with relatively low melting rates.

Analyses of the ashes and slags were made, and it was observed that cokes from the same coalfield had similar ash compositions as regards silica-alumina ratio and SO_3 content.

Chemical analysis showed a sulphur content of about 0·12% in the castings from all of the cokes except one, and this value is not unsuitable for rail chairs. The first metal of each trial was highest in silicon and manganese, and lowest in sulphur and phosphorus, because the first charge consisted of 10 cwt. of chair scrap and 10 cwt. of manganiferous pig-iron (1·5% Mn min.). Owing to its lower temperature the first metal gave inferior mechanical properties.

Since low carbon content charges, when melted in the cupola, tend to pick up more carbon than medium or high carbon charges, it was decided to employ a 50% steel mixture for the carbon and sulphur pick-up tests. Hæmatite pig-iron (broken into quarter pigs) was used, the whole consignment being delivered at one time, and by careful sampling 32 pigs were selected for analysis. Steel in the form of fishplates was sampled in the same way, 20 plates being selected for analysis. Metal charges of 5 cwt., coke charges of 56 lb., and limestone 21 lb. were used.

TABLE I.

CARBON AND SULPHUR PICK-UPS.

Coke ref.	Mean carbon pick-up. Per cent.	Mean sulphur pick-up. Per cent.	Sulphur per cent. in coke.		
			Total.	Com. bustible.	Fixed.
B	0·94	0·046	0·59	0·25	0·34
D	1·07	0·060	0·77	0·66	0·11
F	1·15	0·044	0·55	0·51	0·04
J1	1·03	0·061	0·69	0·67	0·02
L1	0·97	0·052	0·73	0·68	0·05
I	0·93	0·053	0·72	0·68	0·04
H	1·03	0·039	0·56	0·55	0·01
316	1·07	0·058	0·72	0·63	0·09
317	0·92	0·048	0·66	0·55	0·11
M	0·87	0·074	0·75	0·65	0 ·98

With the exception of one coke the sulphur content of the metal, as would be expected, is highest in the first lap. Speaking broadly, the sulphur content then falls progressively during the remainder of the melt. Table I. shows the mean pick-up figures for sulphur and carbon, together with the sulphur contents of the cokes. There is a slight tendency for high carbon pick-ups to be associated with low-sulphur pick-ups.

Examining the carbon pick-up in the individual taps, it is seen that with the exception of two cokes the carbon content is highest in the second tap. A possible explanation of this is that the metal is not sufficiently hot in the first tap to show a high carbon increase, but during the melting of the second charge the bed is still high and at a high temperature.

To obtain correlations between cupola and laboratory results the cokes were next examined by the following procedures :—

Chemical : Analysis (cokes and slags); wet oxidation test; combustibility; reactivity.
Physical : Shatter; calorific value; porosity; compression strength; abradability.
Structural : Macrostructure (Rose's method); microstructure.

A summary of the tests and analyses showed :

(1) Cupola results of the behaviour of 14 different foundry cokes are given. A very complete laboratory examination of the cokes is also reported, special attention having been devoted to macrostructure and microstructure.

(2) Coke merit for a cupola charge ratio of 16 : 1 has been assessed on a basis of metal temperature. Certain cokes were proved to be as good as more famous brands of higher price.

(3) Determinations of the sulphur and carbon pick-ups from eight of the cokes were made in a small experimental cupola. Broadly speaking, the sulphur pick-up of the metal was directly proportional to the total, and to the combustible sulphur contents of the fuels. The carbon pick-up tended to increase with (*a*) the cell-structure openness ; (*b*) the combustibility test rate, and (*c*) the fixed carbon content. Incidentally, the fixed sulphur decreased as the wet oxidation test value increased.

(4) Cupola metal temperatures were determined to within about ± 0·5%, but the results for the best and worst cokes only differed by about 5%. The field for correlating cupola and laboratory tests therefore proved unfortunately to be very narrow. In these circumstances none of the tests can be relied upon to predict the practical cupola properties of a coke of unknown origin, but the most helpful in this respect was the shatter test.

(5) Correlations between the various tests themselves, and the cupola results hint at the following generalisations for these particular samples :—

Cokes giving *low* metal temperatures are *low* in :
(*a*) Shatter index.
(*b*) Rate of wet oxidation.
(*c*) (RI — RIII) reactivity value.
(*d*) Resistance to abrasion ; and high in :
(*a*) Density of cell structure.
(*b*) Resistance to static compression.

(6) If these few cokes are considered in groups of their native coalfields, the following generalisations suggest themselves :

A *decrease* of cupola metal temperature is associated with a *decrease* in :
(*a*) Shatter index.
(*b*) Rate of wet oxidation.
(*c*) (RI — RIII) reactivity value.
(*d*) CO : CO_2 ratio in the combustibility test.

A most useful wall chart of recommended compositions of nickel cast iron for specified purposes (of which over 300 are mentioned) has been issued by the Mond Nickel Co. Ltd., Thames House, Millbank, London, S.W.1. The various compositions recommended are clearly tabulated with key letters for quick reference ; heat-treatment is indicated ; and the reverse of this wall chart gives data covering recommended methods of adding nickel and chromium to cast iron and a table of alloy additions.

The wall chart is available to readers, application should be made to the Bureau of Information on Nickel, The Mond Nickel Co. Ltd., Thames House, Millbank, S.W.1. The information contained in the wall chart is also published in pamphlet form. Readers should then ask for pamphlet BB6.

Physical Factors in the Casting of Metals

A better knowledge of the physical factors which affect properties is of great importance to foundrymen, and in a lecture by Dr. C. E. Desch, F.R.S., before the recent annual meeting of the Institute of British Foundrymen, he indicates which deserve attention, and which may be neglected for practical purposes. This lecture is summarised in the present article.

LABORATORIES in which metallurgical research is conducted are often asked to undertake exact measurements of certain physical properties of metals which exert only a minor influence on the quality of castings, foundrymen being under the impression that difficulties which they experience are connected with a particular property. The main purpose of this lecture was to review the factors involved in the filling of a mould with liquid metal for casting, and to indicate which are like to deserve most attention.

The first condition of obtaining a satisfactory casting is that the metal shall flow evenly into the mould, and shall fill it completely before such freezing occurs as to offer an obstruction to its further flow. Dr. Desch preferred to call this "flowing power," instead of using the terms "coulabilité," "castability," or "fluidity," especially as the latter term has the disadvantage of having a specific physical meaning as the reciprocal of the viscosity.

Roughly, the values obtained for the flowing power will depend on two kinds of factors: one set depending on the conditions of the experiment, including the form, material, and surface of the mould, the casting head and the degree of superheating of the metal before pouring, and the other involving the properties of the metal or alloy. This second set includes: viscosity; surface tension; gas content; formation of surface films, as of oxide or nitride; the range over which solidification takes place; change of volume during solidification; and crystal thrust. There are other factors which affect the quality of the resultant casting, although not among those which govern the flowing power. These include: the contraction in the solid state; the strength at temperatures near to the freezing point; the liability to segregation; and the tendency to form small or large crystal grains; the last being dependent in many instances on the previous history of the metal—that is, on the highest temperature to which it was heated before cooling to the temperature at which it was poured.

Viscosity

The first of the physical properties mentioned, that of viscosity, has been credited with a far greater influence on the flowing power than it actually possesses. In reality, the viscosity of metals is very low, the kinematic viscosity being less than that of water in all the examples investigated, and as it changes only slightly with change of temperature, it is really a negligible factor in casting. A metal which is flowing badly often appears to be viscous or treacly, when the effect is actually due to the surface tension of a thin and tough film, or to the presence of much gas in the form of minute bubbles, producing a foam.

It has been urged that although metals are very fluid above their melting point, yet in the interval between the beginning of freezing and the solidification of the last eutectic or other fusible portion, there is a sudden and even enormous increase in the viscosity. This is quite contrary to what is known of viscosity, and there is no reason to suspect any such discontinuous change.

The diminished flowing power is not due to any increase of viscosity during the process of freezing—in the interval between the liquidus and the solidus—but to some other cause. The most obvious is the obstruction of the channel by the growing crystals, and this is the real reason. If the freezing of the alloy were to begin by the formation of small crystals suspended freely in the liquid, there would be some increase in viscosity, as suspended particles do hinder flow, and a liquid in which more than a small proportion of particles is suspended, if tested in a viscometer, will give a higher value than the same liquid free from solid particles. Actually, such a precipitation of free crystals as a shower is only known to occur when a liquid is strongly undercooled, whilst in most instances the undercooling of metals and alloys is limited to a few degrees at most.

Dendritic crystals projecting into the interior will have a greater effect in retarding the flow than if they were simple polyhedra. Pure metals and solid solutions crystallise mainly as dendrites, whilst intermetallic compounds are more often polyhedral, and eutectics tend to form spherulitic masses, which probably offer the least resistance of all.

One form of measurement of viscosity described by Dr. Desch was that of a disc or cylinder suspended in the molten metal, and on setting this into torsional oscillation, the damping in successive swings is measured, the "logarithmic decrement" being a measure of the viscosity. The viscosity of molten tin was determined at the National Physical Laboratory over a range of temperatures from 240° to 800° C. No discontinuity in the viscosity curve could be found a few degrees above the melting point.

The viscosity of metals plays only a minor part in their casting behaviour, the effects which are attributed to viscosity are mainly due to other causes.

Surface Tension

The surface tension of a metal or alloy is another physical property which may affect the casting quality. Molten metals do not wet their moulds, except in such exceptional cases as mercury or molten tin in a mould of tinned copper, which may be neglected, In a narrow channel therefore, there is a resistance to the flow of the metal owing to its surface tension, but this effect becomes less and less marked as the diameter of the passage is increased. Actually, the amount of the resistance so produced is small in most castings, provided that the metal has a clean surface, a condition which is not always fulfilled, as mentioned below. As a rough indication, the following values may be taken for the surface tensions of some of the common metals, at temperatures not much above their melting points.

Metal.	Temperature. °C.	Surface Tension. Dynes/cm.
Antimony	640	350
Bismuth	269	378
Lead	327	452
Mercury	20	465
Tin	232	526
Cadmium	320	630
Zinc	419	758
Silver	998	923
Copper	1,131	1,103
Gold	1,120	1,128
Iron with 2·2% C.	1,420	1,500
Iron with 3·9% C.	1,300	1,150

Metals of high melting point thus have a higher surface tension than the easily-fusible metals.

An examination of micro-sections of alloys containing primary crystals embedded in a eutectic will show that metals with a high surface tension, such as copper, form crystals with much rounded outlines, whilst when the metal has a low surface tension, such as antimony, it forms

dendrites with sharp angles. Gold gives highly rounded forms, and even below the melting point, sharp-angled crystals of gold, prepared by etching, become rounded if heated. When the first shell of crystals forms at the surface between the metal and the mould, it will make a difference to the flow whether the crystals so produced are angular or rounded, as the rounded forms may be expected to offer less resistance, although it cannot be said that there is any definite evidence on this point.

Effect of Gases on Flowing Power

If gases are being continually evolved from a metal during casting, its flowing properties may be influenced in more than one way A lively evolution of small bubbles, causing an effervescence, as in casting a certain class of steel, may appear to make the metal more fluid, but the effect is probably only apparent, and in a narrow channel there will certainly be an increased resistance to flow. One difficulty in applying data as to surface tension to the case of a metal flowing in a channel arises from the fact that the metal is often not in actual contact with the mould, but is separated from it by a thin layer of gas, either issuing from the metal, or arising from the material of the mould. The "interfacial tension" between metal and solid is then altered, perhaps considerably.

The effect of oxide film on aluminium is to increase the value of surface tension nearly three times. This property of aluminium also affects alloys in which it is present. The difficulty of casting aluminium bronze (the copper alloy containing 8–10% of aluminium) is caused by the formation of such a tough skin, which hinders pouring, and, by becoming broken into fragments, is entangled in the metal, making a dirty casting. Brass forms a much less tenacious film during pouring, and the zinc oxide which is produced breaks up very readily, again causing defects. A brass containing aluminium forms a skin of the tough kind, so that the surface of such an alloy in the crucible shows little evaporation of zinc, unless it be stirred, when the protective film is broken, and a puff of vapour escapes.

The Freezing Range

A pure metal freezes at a constant temperature, but in most alloys the process extends over a range, and the extent of this range is of importance in determining the flowing power. Eutectic alloys, and such as occupy a minimum on the freezing-point curve, as in the alloys of copper and gold, freeze at a constant temperature, like pure metals. Portevin and Bastien concluded, from a study of a number of alloys of low melting point, that the flowing power varies (in any one system of alloys) inversely at the solidification interval, and is thus greatest for pure metals and eutectics.

Experiments have been extended to ternary alloys, and it is found, as might have been expected, that a ternary eutectic, which freezes at a constant temperature, has the greatest flowing power of all the alloys included in the system. Once more the flowing power is (roughly) inversely proportional to the range of temperature over which solidification takes place.

Several methods of determining the actual change of volume that takes place during the process of freezing have been employed, but Dr. Desch describes an apparatus used for experiments, using a differential method. This, consists essentially of two similar bulbs of glass or silica immersed side by side in a stirred bath of oil or fused salts, so that they can be brought accurately to the same temperature, and communicating with a differential manometer. One of the bulbs contains a known quantity of the metal, the space above it being filled with nitrogen, whilst the other contains only nitrogen. The differences of expansion or contraction recorded by the manometer then correspond with the changes of volume of the metal. By this method it is possible to measure accurately the change of volume on freezing, distinguishing that part which corresponds with the separation of primary crystals from that due to the eutectic.

The only pure metals which expand on freezing are bismuth, antimony and gallium, and this exceptional property affects their alloys, neutralising the contraction due to the other metal, to an extent depending on the composition. Stott has shown how the contraction of an alloy may be calculated with fair accuracy from a knowledge of the behaviour of its component metals, remembering that the variation of specific volume with composition is not far from linear, in both the liquid and solid states.

Thrust of Growing Crystals

A factor which is commonly ignored is that of the thrust which may be exerted by growing crystals. An apparent expansion during solidification is sometimes observed when determination of density shows that the volume has actually diminished.

It was confirmed for a number of copper alloys that this expansion increases as the freezing range becomes greater, especially such alloys with zinc. Determinations of density show that the alloys have really contracted during freezing, and that the apparent increase of volume is represented by a considerable porosity, distributed throughout the test cast bar. A part of this may be accounted for by the liberation of dissolved gases during freezing. The growth of a mass of crystals, if of dendritic form, may, and often does lead to an outward push, the crystals seeming to repel one another as the liquid between them freezes. The result is that an outer shell is formed, and the contraction of the liquid metal contained in it, as it freezes in its turn, leaves small cavities, which may be so distributed that the casting appears solid, unless examined under the microscope.

Antimony, when present to the extent of 10%, reduces the contraction to a very small extent. As the effect appears in the outermost shell of crystals, it is chiefly found in the narrow portions of a casting, and becomes negligible where the section is large. For the purposes of the foundry this apparent expansion is the same as a true expansion in casting of small section, but it has the effect of making the shrinkage allowance depend on the size. True expansion is exceptional in alloys.

Other Physical Factors

There are other physical factors which enter into the process of flow and solidification. Such are the latent heat and the thermal conductivity. More accurate values of the latent heat of fusion of metals are needed, only a few of the pure metals having been studied satisfactorily.

Segregation is one of the factors which determines the quality of the resulting casting, but it is of a different character to the purely physical properties we have considered. Mention should be made of a possible effect of the degree of superheating to which the metal has been subjected before pouring When heating has been carried far, and the metal is allowed to cool before casting, certain properties appear to depend on the maximum temperature which has been reached, the previous history of the liquid leaving an impress on its properties

This is particularly true of the grain size. It is often found that a larger grain size is obtained when the maximum temperature reached has been high, than when it has been low, although the actual degree of superheat at the moment of pouring is the same. Dr. Desch gave some interesting data and theories regarding crystal growth influencing this factor.

Dr. Desch acknowledges that the acquired skill of a practical founder is something which, whilst not subject to quantitative expression, stands high in the rank of the factors controlling the quality of the casting, and pays a tribute to the value of the Institute of British Foundrymen, in which men who have this knowledge can meet to compare their experiences, and so add to the progress of this ancient craft, now based on a scientific study of metals.

Foundrymen Visit Midland Works

Works visits play an important part in the annual conventions held by many technical institutes, and that of the Institute of British Foundrymen, recently held at Derby, proved to be no exception. Judging by numbers who participated, these visits maintain their interest, and in this article brief reference is made to the works included in the arrangements.

IT is probably surprising that there should be a desire among those engaged in various forms of industry to take a busman's holiday. Yet there are distinct advantages in making personal contact with the executives of works who are faced with problems very similar to your own. Not only does it tend to enlarge one's outlook in regard to organisation and methods of production in other works, but it causes the visitor to be more critical of his own work than he would otherwise be. To the foundryman these visits are especially useful, because of the wide differences existing between one foundry and another, and in a practical sense they may provide ideas which are of more immediate application than can be obtained at technical sessions. In connection with the recent Annual Convention of the Institute of British Foundrymen, five works visits were arranged, and in addition a large number of members visited Loughborough College; a brief reference to these will be of interest.

The steel foundry at Qualcast, Ltd.

Qualcast, Ltd., Derby

This company originated as a stove plate foundry in 1801, in Sheffield, but in 1849 the business was transferred to Derby under the name of the Derwent Foundry Company, which became a public company in 1928 under the above title. After the war this company commenced to specialise in the manufacture of light repetition castings, with an output of about 15 tons per week. The demand for its products has grown very rapidly and to-day the output from the grey-iron foundry alone is approximately 160 tons per week.

The grey-iron foundry is designed and equipped for dealing with small and medium sized work of a repetition character. The main moulding shop is about 340 ft. by 210 ft., and is equipped mainly for the production of light, intricate castings for the automobile, electrical and allied industries. Installed is a range of hydraulic, pneumatic and hand squeezers, as well as ram moulding machines. The core shop also is well equipped, comprising sand-mixing plant, sand and core conveyers vertical dryers, and a battery of core blowing machines.

The main foundry is served by two cupolas of 12 tons per hour capacity, with a 3-tons per hour cupola for special irons. Recently, however, this firm commenced the manufacture of special heat-resisting castings, for which a new foundry was built and equipped with a 30-cwt. Stobie three-phase arc furnace.

An important section of the work done is the manufacture of lawn mowers and this firm can claim to be the largest makers outside the U.S.A.. with a factory established in Australia which has the largest output in that continent.

Ley's Malleable Castings Co., Ltd.

These works were founded in 1874 by the late Sir Francis Ley, who was the pioneer in this country in the manufacture of "blackheart" malleable castings, and since that time the firm has specialised in these castings. Some indication of the progress achieved will be appreciated from the average weekly production, which is approximately 400 tons. When it is realised that the average weight of the castings produced is about 2 lb. the extent of the organisation will be understood. These blackheart castings are used extensively in the automobile, agricultural, conveying, electrical, and general engineering trades, particularly by firms requiring high machinability. It is claimed that these works produce about 40 per cent. of the total malleable castings made in Great Britain.

The oldest foundry building is 744 ft. long and 153 ft. wide, with an annexe 250 ft. long by 75 ft. wide. A grey-iron foundry is attached, equipped with a cupola of 3½ tons per hour capacity, the output of which is for the company's own use. The melting plant in the old foundry conprises one 10-ton and five 6-ton air furnaces. In 1926 a new foundry, 362 ft. by 164 ft. was put into operation, equipped with two pulverised-fuel-fired air furnaces, each of 20-tons capacity, and with a waste-heat boiler. Two further foundries were built in 1934, one being 368 ft. by 152 ft. and the other 342 ft. by 153 ft., each being equipped with similar melting plants to that installed in the 1926 foundry. The waste-heat boilers are the Stirling water-tube type and the steam raised is used to generate the whole of the electricity used in the works, the hot air for heating the shops, and preheating the secondary air for the melting furnaces.

The foundries are equipped with air squeeze and jolt moulding machines, while sandslingers are also used. Cores are made in shops adjoining the foundries; core-blowing machines are used where possible and the cores are transported by steel band conveyers to and from coke-fired continuous vertical ovens.

Part of Qualcast's grey-iron foundry.

One of the light castings shops at Bamfords, Ltd.

The problem of fettling such a large number of relatively small castings is a difficult one, but at these works the work is chiefly done by pneumatic chisels and grinders, while modern shot blasting equipment is employed for cleansing the castings. The annealing shops are equipped with 24 periodic ovens fired by pulverised fuel; they are fitted with recording pyrometers.

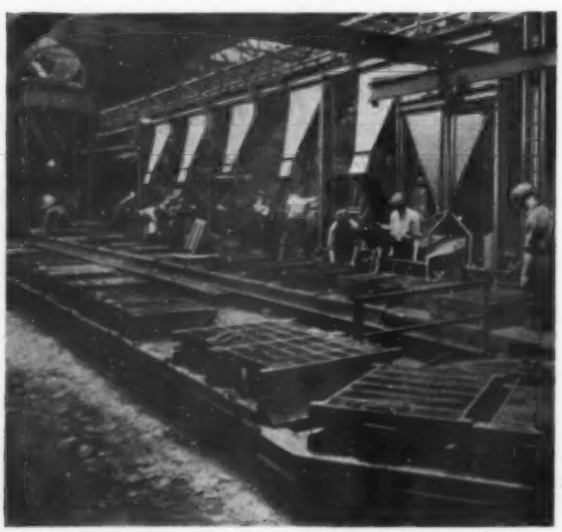
There are two large central Fraser & Chalmers pulverising plants, equipped with Ruggles-Cole dryers and Hardinge mills. These supply pulverised fuel to forty points of consumption on furnaces and ovens. The power plant comprises two Metropolitan-Vickers turbo-alternators, 1,350 kw. and generates about 140,000 units per week. The power house also includes two Tilghman low-pressure compressors at 30 lb. and an Alley McLellan high-pressure compressor at 100 lbs.

Considerable attention is given to control of materials and processes, and two laboratories are adequately equipped and staffed, not only for the routine sampling and checking inseparable from well-organised works of this character, but for carrying out research work.

Bamford's, Ltd.

Founded in 1871, this firm has progressed steadily and to-day it is one of the largest agricultural machinery works in Great Britain, covering an area of 30 acres and manufacturing machinery which goes to all parts of the world.

Mechanised foundry arrangement by Herbert Morris, Ltd.



From the initial stage the firm possessed its own foundry and, apart from malleable castings, continues to make all its own castings for a large range of machines, which include hay machinery, barn machinery, diesel, petrol and paraffin engines, fertiliser distributors, grassland harrows, potato diggers, and pumps. To-day there four shops, all devoted to the making of these castings.

The foundry, which covers an area of nearly 7,000 sq. yds., has recently been thoroughly reorganised, and is producing approximately 20 tons of castings daily. It is served by three modern cupolas of 2, 3 and 6 tons per hour capacity. The sand plant is equipped with a 3 tons per hour Simpson Mixer, and an interesting feature is the coal-dust plant, which is a product of the works. The moulding department, divided into three sections, is well equipped with moulding machines. The light castings section has 15 squeezer-type machines, whilst the medium section is equipped with eight jolt ram machines, and the main section, containing 12 turnover and 2 jolt ram machines, has two bays exclusively for the loose pattern and plate moulders. The non-ferrous plant is in this section and deals with brass, bronze and aluminium. The core shop is eqiupped with modern ovens and excellent storage for dried cores.

Although the chief interest of the visitors was in the foundry, they also paid brief visits to the machinery, assembling, woodworking and painting shops, where they saw the modern farm implement in its various stages of production, from the raw materials to the finished machine.

The Stanton Ironworks

Foundrymen had a double interest in the visit to these works. In addition to being famous for its centrifugal pipe-casting, an operation in which this company are pioneers, it claims to produce more foundry pig iron for the open market than any other firm in Great Britain. The company have eleven blast-furnaces, five of which are at the Stanton Works, four at Holwell, near Melton Mowbray, and two at Wellingborough.

The members visiting these works were much interested in the manufacture of Stanton "new" spun iron pipes under the Delavaud and Mairy patents. The pipes are cast without chill in revolving steel moulds, a method which, it is claimed, produces a combined tensile and ductile strength never before obtained in iron pipes. Production is continuous, as the moulds require no preparation other than the mechanical application of the fine coating of ferro-silicon necessary to obviate chill. Owing to the very heavy demand for the smaller sizes of these spun iron pipes, the company have recently erected a special plant solely for the production of 3 in. diameter pipes, 4 yds. long. This plant has been fully mechanised, and rapid production is further assisted by the fact that each machine produces only one size of pipe.

Sand-cast "specials" and large diameter pipes are still produced at the Stanton New Works by the sand-cast process. Of the various types of large castings produced on these works, perhaps the most important are tunnel segments, for which the company have been noted for many years. Here were produced the 82,000 tons of cast-iron segments which line the Mersey Tunnel.

Herbert Morris, Ltd.

Founded in 1884, in London, this firm moved to Loughborough in 1904. Development and extensions absorbed the available ground, and in 1922 a new site of 74 acres was secured, and by 1924 large works were in occupation This has since been twice extended and the total floor. space of the works now exceeds 22 acres. There are now five works, known respectively as the north, south, east, west and the boiler works, constituting what is probably the largest plant in the world making lifting and conveying machinery exclusively.

The interest of the visitors was centred, not so much in the foundry, the machine and erecting shops, but in the specialised conveyer equipment for foundries and other shops. Here are facilities for mechanising the foundry and for facilitating transport of sand, moulds, and in relieving the operator of the heavy work involved.

Much interest was shown in the north works, where large electric overhead cranes are built, together with goliath cranes, steam jib cranes, electric jib cranes, and a wide variety of conveyers and elevators. An especially interesting section of the works is the testing bay, where electric cranes are lifted on to variable span gantries of tested with the exact equivalent of the customer's current supply. The efficient handling of the materials of manufacture has naturally received particular attention, and visitors saw how simply this has been secured. Transporting here is reduced to a science.

Loughborough College

Established in 1915 as the first controlled centre for the training of war workers, Loughborough College came to be regarded as an experiment in education in 1918, and the "Training on Production" method inaugurated by Dr. Schofield gives great value to the work. Thus, realism is a strong factor, and is further enhanced by the fact that students spend alternate weeks on theory and on actual productive work, the academic study relating to workshop practice throughout the course, and working on a thirty-hour week in the classrooms and laboratories, the alternate weeks of productive work in the shops being of 40 hours.

The student receives comprehensive and practical training in all departments, workshops being very fully equipped indeed and including: foundry, pattern, cabinet and saw mill; general machine shop, with 21 centre lathes with swings of 6 in. to 26 in., shaping machines and capstan lathe; heavy lathe shop; automatic machine shop, containing examples of all types of semi-automatic and fully automatic lathes for both bar and chuck work; precision, fitting, tool and gauge-making shop; grinding shop; heat-treatment laboratory; oxy-acetylene and electric welding plant; milling machine shop; electric fitting and erection shop; fitting and erecting shops, motor vehicle repair and reconditioning shop, with accommodation for 20 cars and pit provision for 12 cars, equipped for complete engine and chassis overhauling; drawing office, having two electric copying machines; heat engine testing and research laboratories, with Heenan and Froude electric dynamometers and air brakes capable of measuring b.h.p. of internal-combustion engines up to 450 b.h.p. at speeds up to 2000 r.p.m. A two-ton Morris double girder overhead crane is provided for handling heavy stores, and there is an electricity generating station equipped with diesel, gas and oil engines.

As instance of the thoroughness of tuition under practical working conditions can be mentioned the fact that actual work is produced and marketed, including both ferrous and non-ferrous castings, these being up to three tons in weight and inclusive of parts for engines, condensers, dynamos, motors, pumps, and other skilled productions.

It can be said that by the time the student reaches the end of his fifth year at the College he leaves, having reached degree standard on the theoretical side and having served an apprenticeship embracing all branches of engineering. In view of the efforts of the Institute in promoting educational facilities for the training of foundrymen, the visit to this College proved of great interest, and the methods adopted were very favourably commented upon.

Sir Herbert Gepp, director of the North Australian Aerial Geological and Geophysical Survey, reports evidence of the existence of millions of tons of iron ore in Queensland, at a location near Portland Roads. The deposit will require detailed examination, but there is every indication that here exist millions of tons of valuable ore which would not entail difficulties in working.

Drilling for Oil in Sussex

ABUNDANT supplies of oil have become a necessity for modern civilisation, whether in peace or emergency conditions, and particular interest is attached to the efforts which the Anglo-American Oil Co. Ltd., are making to find oil in this country. An important bid under the British Oil Exploration scheme, was started in the first week of June, when Lord Apsley, deputising for the Rt. Hon. Sir Thomas Inskip, Minister of Defence, set the new oil-drilling plant in motion at Grove Hill, Hellingly, Sussex.

The drilling of this test well is the first attempt of the Anglo-American Oil Company actually to bore for oil in this country, and involves the use of tools and methods seldom seen in Great Britain. The rotary system of boring is being employed. A solid-steel bit is attached to the end of a steel pipe which is rotated from the surface by a "rotary table." The pipe is extended by 30-ft. sections threaded for attachment, continued extension being made as the boring descends. Mud in a semi-viscous condition is pumped under steam pressure down the piping while the bit is rotating, the mud washing away the rock fragments cut by the bit, and floating them to the surface. Settling tanks are used, and the mud is recirculated. The bit makes a hole of 17-in. diameter.

General view of the location with its derrick constituting a new landmark in Sussex

A 122-ft. derrick is used for the withdrawal of the sections of the drill pipe for changing the bit, and a strong steel cable passes from a hoisting drum on the derrick floor and over the tope of the derrick. Steam power is generated from three 100-h.p. boilers, and the pressure is 150 lb.

No granite or other volcanic rocks are expected to be encountered, the majority will be sands and shales and occasional strata of hard limestone. Samples of rock will be taken at intervals to provide valuable indications of possible pressence of oil in the lower strata. These samples will be obtained by using a hollow core barrel instead of the bit, thus securing a solid core of the strata.

When necessary, the hole will be lined with steel pipes slightly less in diameter than the hole, and fixed in position by pumping liquid cement around them. Smaller piping is used at the lower depths, giving telescopic effect. The plant has the ability to drill down to over 8,000 ft.

The Petroleum (Production) Act of 1934, established oil prospecting on a sound basis in this country. The Anglo-American Company holds licences over nearly 500 square miles, most of this is in Sussex and Hampshire, and a small area in Scotland. The same company has also made application to the Department of Mines for licences covering about 2,266 square miles in other parts of the country.

The results of the first Sussex boring will be anticipated with great interest.

Bruntons, Ltd., Musselburgh, Scotland, have sent us an interesting booklet which deals with their stainless steel products. This firm has extensive experience in the working of this steel and in addition to wire and rope, a wide range of sections is given, including turbine blading, parking pieces, shrouding and locking strip, all produced in stainless steel.

Reviews of Current Literature

Metallurgy of Lead and Zinc

VOLUME 121* of the "Transactions of the American Institute of Mining and Metallurgical Engineers Inc." deals with the metallurgy of lead and zinc in a series of fully informative papers. The preface to the book states that during the period since the World War, few papers of major importance have appeared on the production and refining of lead and zinc, although many improvements in technique have been made, which have attracted little attention because they were merely developments of existing practice. Other changes of a more radical nature have also been made, but for business reasons they have been given little publicity. In seems appropriate at this time that the Rocky Mountain Fund Committee of the A.I.M.M.E. should sponsor a volume on "Lead and Zinc Metallurgy," and that the Committee on Reduction and Refining of Lead and Zinc should attempt to secure papers on the various phases of the subject. The response to requests for papers has been gratifying.

The many papers include details of blast-furnace lead smelting at various American plants, lead smelting in the Federal improved mechanical ore hearth, sintering lead ores, study of drosses, the Betts process of electrolytic lead refining, chloring dezincing in lead refining, debismuthizing lead with alkaline earth metals, including magnesium, and with antimony ; two papers on fume and dust collection ; sintering of zinc ores, horizontal and vertical retort practice for zinc, manufacture of silicon carbide retorts, electrolytic zinc plants, the Trollhätten electrothermic zinc-smelting process, reduction of zinc ores by natural gas, the Waelz process, direct process zinc oxide, treatment of slag and residues and intermittent zinc distilling from ore, among others.

It is interesting to note that the Waelz process has made considerable progress, and that, in the course of 12 to 15 years, eight plants have been built in Germany, five in the United States of America, one each in England, Italy, Japan, Greece and Belgium, so that there are altogether 41 kilns having a total capacity of about one and a-half million tons, and producing over 200,000 tons of zinc oxide, and 25,000 tons of lead oxide per annum.

One plant quoted is at Sturzelburg, and treats purple iron ore, volatilizing off the zinc and leaving an iron clinker for smelting.

The recovery of tin is another interesting application of the Waelz process. Tin can be volatilized as a sulphide with a high degree of efficiency. The tin ore is mixed with pyrite, gypsum or other sulphur-bearing materials and fed to a Waelz kiln. During the reaction in the kiln the tin oxide is converted into tin sulphide, and in this form is easily fumed off. This tin sulphide is reconverted into zinc oxide by the hot flue gases, and is precipitated out from them in that form. The residue discharged from the kiln averages, as a rule, 0·1 to 0·2% Sn, which corresponds according to the content of the ore, to a 95 to 99% recovery.

The volume is well illustrated and contains ample diagrams of plant layout and equipment.

Bearing Metals and Alloys

THE subject of bearing metals and alloys, their structure, qualities and behaviour, is of intimate interest to all engineers and designers, and is covered very fully in this book. Intended more for the works manager and designer than for the research worker, the author gives less emphasis to the academic aspect of the subject, because he contends that the engineer who uses white metals and bronzes is more concerned with the way in which they stand up to their work than with equilibrium diagrams. It therefore treats of the practical side very largely, giving just as much of the theoretical side as is considered necessary for proper understanding of the subject.

Reference is made to the complexity of some of the alloys on the market, and to the fact that such complexities are neither necessary nor desirable. The effects of the addition of small quantities of metals other than those of which the alloys are fundamentally composed is dealt with at some length, to give a key to the estimated effects of impurities in the scrap with which the engineer, who uses his own bearing scrap, would necessarily have to contend.

The first chapter, devoted to the development of bearing metals on an historical basis, is both interesting and informative, and a useful section is that where the problem of alloys that have been classified or named in an erroneous manner is discussed.

Lubrication of bearings is dealt with thoroughly, and the question of graphite is covered in detail. The author's careful compilation of references are extremely valuable. Interesting data regarding bearing seizure is contained in that chapter : the phenomenon known as "seizing" is the usual result of a hot bearing, and is only too well known to most engineers, whose whole aim and object in putting in a new bearing is to avoid this particular trouble. It is commonly thought to be due to lack of lubricant between the journal and the bearing surfaces, but experiments made at the National Physical Laboratory showed that seizing might occur whilst the oil film was still many molecules thick. The bearing seizes, not when the oil film ceases to exist, but when the stress on the oil reaches a limit which is a function of the viscosity and other properties of the oil.

The material of which the bearing surface is made is important, but the oil is the chief factor. In order that oil may be dragged in between the surfaces of the journal and the bearing surface, it must adhere to both. Mercury is not a good lubricant, because it does not adhere ("wet" the surfaces), and the strength of the bond, the shearing of which causes seizing, depends on the oil and the metals with which it is in contact. If the shearing forces exceed the strength of the bond it breaks down, and seizing occurs, even though at the time of the breakdown the film is of appreciable thickness. A rise in temperature naturally lowers the bond because it lowers the viscosity of the oil. The superiority of animal and vegetable fats is thus demonstrated as due to the stronger bond which they form with bearing surfaces in comparison with that formed by ordinary mineral oils.

This useful book contains chapters on bearing metals in general ; crystal structures ; effects of copper, nickel, cobalt, aluminium, arsenic, cadmium, thalium, mercury, thorium, zinc, molybdenum, tungsten, tin, phosphorus, manganese, antimony, silicon and iron ; whilst such factors as resistance to wear and other physical properties are given the space they deserve. The book is written in a clear, straightforward style ; well illustrated with diagrams, tables and plates.

By Henry Norman Bassett. Published by Edward Arnold and Co., 41-43, Maddox Street, London, W. 1. 25s. net.

Additions to the *Noral Handbook* have been published by the Northern Aluminium Co. Ltd., comprising alterations and additional pages, these covering heat-treatments, tables of typical physical properties of aluminium and its alloys, British standard specifications, manufacturing limits for various of the N.A. series alloys in plate and sheet, a comprehensive section dealing with extruded sections and alterations that have been made in the manufacturing limits of certain alloys, the latter involving reductions in the minimum thicknesses available.

A further development in the Northern Aluminium Company's range of alloys is indicated by the inclusion of the mechanical property specification of heat-treated alloy N.A. 13 SQA.

A series of general pages dealing with heat-treatment of aluminium alloys is also issued. Copies are available on application to Northern Aluminium Co. Ltd., Bush House, Aldwych, London, W.C. 2.

* *Transactions* of the American Institute of Mining and Metallurgical Engineers, Inc. "Metallurgy of Lead and Zinc." Vol. 121. 29, West 39th Street, New York, N.Y., U.S.A. 1936.

Business Notes and News

Coventry Machine Tool Works Extensions

Large-scale extensions, which add 5,200 sq. ft. and 50% productive capacity to the Coventry factory of Coventry Machine Tool Works, Ltd., makers of forging plant, have now been completed. The principal extension, covering an area of 3,400 sq. ft., will be used for housing an entirely new development in forging plant manufacture—namely, the building of large horizontal forging machines, weighing 150 tons upwards, which can forge bars of steel very much greater than it has been possible hitherto to forge with plant made in this country. Horizontal forging plant of this magnitude have, in the past, only been made in Germany and the United States.

Designed for use in the motor-car, ball-bearing, shipbuilding, agricultural machinery and other engineering industries, the makers claim that the new plant will save material, lower production costs, increase output, and produce better forgings.

Gift for Foundry Research

At the annual conference of the Institute of British Foundrymen, held at Derby, it was announced by Mr. C. W. Bigg, following his installation as president, that the directors of Qualcast Ltd. offered a gift of £500 to the Institute as a nucleus of an endowment fund to be used to promote the work of the Technical and Educational Committees.

The offer will necessarily be considered by the Council, but Mr. S. H. Russell, in expressing thanks to the directors of Qualcast Ltd. had not the slightest hesitation in saying that it would be accepted and administered in the way the donors desired. This was supported by Mr. J. W. Gardom, who referred to the importance of fostering research work in the foundry industry.

Increased Activity in Rhodesia—Tin and Tungsten

Preliminary work in the Tshontanda fields in the Wankie area of Rhodesia indicates the presence of a tin lode with a 20-ft. width and consistently rich ore. Tungsten deposits are now being compared, for magnitude and uniform richness, with the copper fields of Northern Rhodesia. Operations have been in progress for two years, the country is difficult, but the first plant with 150 tons daily capacity will shortly be working, and a power-line is being run from the small town of Wankie, some 20 miles away. Pegging now covers over 50 sq. miles.

Supplies of British Ores and Imports of Scrap for Steelmaking

The increasing scarcity of steel scrap in 1936 led to important changes by steelmakers, the proportions of scrap and of pig-iron, and/or hot metal in a 10-ton ingot being: 1935, 5·92 tons and 4·66 tons, respectively, and in 1936, 5·87 tons and 4·72 tons, respectively, these being average figures. Steelmakers' consumption of their own pig-iron and scrap increased from 51·6% in 1935 to 53·2% in 1936.

The effect of this saving was shown by the fact that internal consumption of steelmaking materials increased by 1,225,000 tons, whilst external purchases increased by 778,000 tons only. The scarcity of scrap combined with the increase of scrap metal prices to influence the above change. Even so, the industry imported scrap to the value of £3,074,000 in 1936, an increase of over £2,000,000.

Economies in blast-furnace operation resulted from the demand for increased production, burden, for instance, was reduced from 56·33 cwt. to 55·81 cwt. per ton of pig-iron, and more modern coke-oven practice resulted in increased fuel efficiency, a reduction from 33·58 to 33·16 cwt. of coal equivalent being recorded.

2,786,000 more tons of iron ore were needed for the 1,297,000 additional tons of pig-iron produced in 1936. British quarries supplied 1,750,000 tons (approx.), and 1,000,000 tons were imported. Foreign supplies did not show themselves capable of speedy increase, and supplies from Newfoundland, Sierra Leone and the Labrador coast have increased three-fold in the past two years. Nearly half of the increased ore production in this country came from Oxfordshire and Northamptonshire, but the comparatively low iron content of those ores increased coke consumption, and made the coke shortage position more difficult.

Steel Casting for Speciality Machine

A steel casting, remarkable and interesting, because of its design, and because hitherto a casting of this type has not been made from steel, is shown in the accompanying illustration. It was recently produced in the steel foundry of Edgar Allen & Co., Ltd., for a speciality machine designed by Messrs. Kinetor (Development), Ltd. The overall length of this casting is 169⅞ in. The measurement at the highest point is 127·15/16 in., and the width at the greatest point 25½ in. The rough weight of the casting is 17tons 4cwts. 3 qrs., and it constitutes an excellent sample of Edgar Allen steel foundry work, and is a striking contrast to some of the smaller steel castings produced at the same works, which weigh only a few ounces.

Large steel casting by Edgar Allen & Co. Ltd.

British Rolling Mills Export Orders

In their recently extended works we understand that Messrs. W. H. A. Robertson & Co., Ltd., of Bedford, are fully occupied in executing important orders recently received for their standard cold rolling mills and auxiliary machinery. Included in these orders are three complete trains of tandem four-high continuous steel-strip rolling mills for U.S.S.R.; a reversible high-speed mill for wide aluminium strip is in course of construction, also for Russia; another important order is a reversible high-speed four-high cold strip mill for Poland. This latter mill is fully equipped in accordance with the latest practice and will be capable of finishing strip up to 40 ins. wide in heavy continuous coils.

Among other contracts of interest are aluminium-strip mills and tandem wire flattening mills for Sweden; four-high steel-strip mills for France, in addition to many important rolling mills and wire drawing installations for well-known firms in this country and the Dominions.

Bright Annealing Furnace Installations

About 25 dry bright annealing furnaces of 50 kW rating have been installed by the Electric Resistance Furnace Co., Ltd., of London; one of the latest has been supplied to Messrs. Connollys (Blackley) Ltd. for annealing bright copper wire in all gauges down to 0·002 in. diameter, the heating bell operating from 3-phase, 400 volt supply.

The wire can be treated in coils or wound on spools, is stacked on one of three charge plates, each of which has a waterseal around the base; and a light metal hood is lowered, sealed and the interior purged by passing nitrogen through the hood. The mixture is purified to remove all traces of sulphur, dried and stored in a small container, then circulated round the charge by internal fans during the 420-500°C. annealing process, this taking 45 to 60 minutes.

The bell shaped furnace is lowered over the hood for the annealing process. After annealing, the hood and charge are cooled by water spray. A concrete heat insulating bottom is provided for the heated bell to rest upon should none of the three hoods be ready to receive it; the one furnace serving three charge bases for continuous working.

MARKET PRICES

ALUMINIUM.

98/99% Purity		£100	0	0

ANTIMONY.

English		£83	10	0
Chinese		69	0	0
Crude		36	10	0

BRASS.

Solid Drawn Tubes	lb.	0	1	0¼
Brazed Tubes	,,	0	1	2½
Rods Drawn	,,	0	0	11
Wire	,,	0	0	10
*Extruded Brass Bars	,,	0	0	6¾

COPPER.

Standard Cash		£57	5	0
Electrolytic		62	0	0
Best Selected		62	15	0
Tough		62	5	0
Sheets		95	0	0
Wire Bars		64	0	0
Ingot Bars		64	0	0
Solid Drawn Tubes	lb.	0	1	2¼
Brazed Tubes	,,	0	1	2¼

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	£0	5	1½
‡Ferro Tungsten	,,	0	5	0
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.				
NOMINAL: 2–4% Carbon, scale 11/– per unit	ton	30	10	0
NOMINAL: 4–6% Carbon, scale 7/– per unit	,,	22	7	6
NOMINAL: 6–8% Carbon, scale 7/– per unit	,,	21	12	0
NOMINAL: 8–10% Carbon, scale 7/– per unit	,,	21	12	0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/– per unit	,,	33	0	0
Guar. max. 1% Carbon. scale 12/6 per unit	,,	36	0	0
§Guar. max. 0.5% Carbon, scale 12/6 per unit	,,	37	10	0
‡Manganese Metal 97–98% Mn	lb.	0	1	3
‡Metallic Chromium	,,	0	2	5
§Ferro-Vanadium 25–50%	,,	0	12	8
§Spiegel, 18–20%	ton	8	5	0
Ferro Silicon— Basis 10%, scale 3/– per unit nominal	ton	10	0	0
20/30% basis 25%, scale 3/6 per unit	,,	13	10	0
45/50% basis 45%, scale 5/– per unit	,,	11	15	0
70/80% basis 75%, scale 7/– per unit	,,	16	15	0
90/95% basis 90%, scale 10/– per unit	,,	28	17	6
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	15	15	0
§Ferro - Carbon Titanium, 15/18% Ti	lb.	0	0	4½
Ferro Phosphorus, 20–25%	ton	22	0	0
§Ferro-Molybdenum, Molyte	lb.	0	4	9
§Calcium Molybdate	,,	0	4	5

FUELS.

Foundry Coke—				
S. Wales	£1 12 0 to 1	13	0	
Scotland	—		—	
Durham	—	1	15	6
Furnace Coke—				
Scotland	—	1	8	0
S. Wales	—	1	7	6
Durham	—	1	17	6

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£83	0	0
*Commercial Ingots		67	0	0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0	1	1
*Cored Bars	,,	0	1	3

MANUFACTURED IRON.

Scotland—				
Crown Bars,	£11	17	0	
N.E. Coast—				
Rivets	11	15	0	
Best Bars	12	10	0	
Common Bars	10	15	0	
Lancashire—				
Crown Bars	11	17	6	
Hoops	12	15	0	
Midlands—				
Crown Bars	11	17	6	
Marked Bars	14	7	6	
Unmarked Bars		—		
Nut and Bolt Bars	10	15	0	
Gas Strip	12	15	0	
S. Yorks.—				
Best Bars	11	17	0	
Hoops	12	15	0	

PHOSPHOR BRONZE.

*Bars, " Tank " brand, 1 in. dia. and upwards—Solid	lb.	£0	1	1
*Cored Bars	,,	0	1	3
†Strip	,,	0	1	1¼
†Sheet to 10 W.G.	,,	0	1	1½
†Wire	,,	0	1	3¼
†Rods	,,	0	1	4
†Tubes	,,	0	1	6½
†Castings	,,	0	1	3½

†10% Phos. Cop. £33 above B.S.
†15% Phos. Cop. £38 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

PIG IRON.

Scotland—				
Hæmatite M/Nos.	£6	3	0	
Foundry No. 1	5	15	6	
,, No. 3	5	13	0	
N.E. Coast—				
Hæmatite No. 1	6	3	0	
Foundry No. 1	4	3	6	
,, No. 3	4	1	0	
,, No. 4	4	0	0	
Silicon Iron		—		
Forge	4	0	0	
Midlands—				
N. Staffs. Forge No. 4	4	3	0	
,, Foundry No. 3	4	6	0	
Northants—				
Foundry No. 1	4	6	6	
Forge No. 4	4	0	6	
Foundry No. 3	4	3	6	
Derbyshire Forge	4	3	0	
,, Foundry No. 1	4	9	0	
,, Foundry No. 3	4	6	0	
West Coast Hæmatite	6	8	6	
East ,, ,,		—		

SWEDISH CHARCOAL IRON AND STEEL.

Export pig iron, maximum percentage of sulphur 0·015, of phosphorus 0·025. Per English ton	Kr.180
Billets, single welded, over 0·45 Carbon. Per metric ton	Kr.315-385
Per English ton	£16 5 0/£19 17 6
Wire Rods, over 0·45 Carbon. Per metric ton	Kr.365-415
Per English ton	£18 17 6/£21 15 0
Rolled Martin Iron, basis price. Per metric ton	Kr.315-330
Per English ton	£16 5 0/£17 0 0
Rolled charcoal iron, finished bars, basis price. Per metric ton	Kr.360
Per English ton f.o.b. Gothenburg.	£18 12 6

SCRAP METAL.

Copper, Clean	£47	0	0	
,, Braziery	43	0	0	
,, Wire		—		
Brass	30	0	0	
Gun Metal	45	0	0	
Zinc	14	15	0	
Aluminium Cuttings	74	0	0	
Lead	19	10	0	
Heavy Steel—				
S. Wales	3	10	0	
Scotland	3	6	0	
Cleveland	3	7	0	
Cast Iron—				
Midlands	3	5	0	
S. Wales	3	10	0	
Cleveland	4	2	6	
Steel Turnings—				
Cleveland	2	12	6	
Midlands	2	5	0	
Cast Iron Borings—				
Cleveland		—		
Scotland	2	2	6	

SPELTER.

G.O.B. Official		—		
Hard	£19	0	0	
English	23	5	0	
India	20	0	0	
Re-melted	20	0	0	

STEEL.

Ship, Bridge, and Tank Plates. Scotland	£11	10	0	
North-East Coast	11	10	0	
Midlands	11	10	0	
Boiler Plates (Land) Scotland	12	0	0	
,, ,, (Marine) ,,		—		
,, ,, (Land), N.E.Coast	12	0	0	
,, ,, (Marine) ,,		—		
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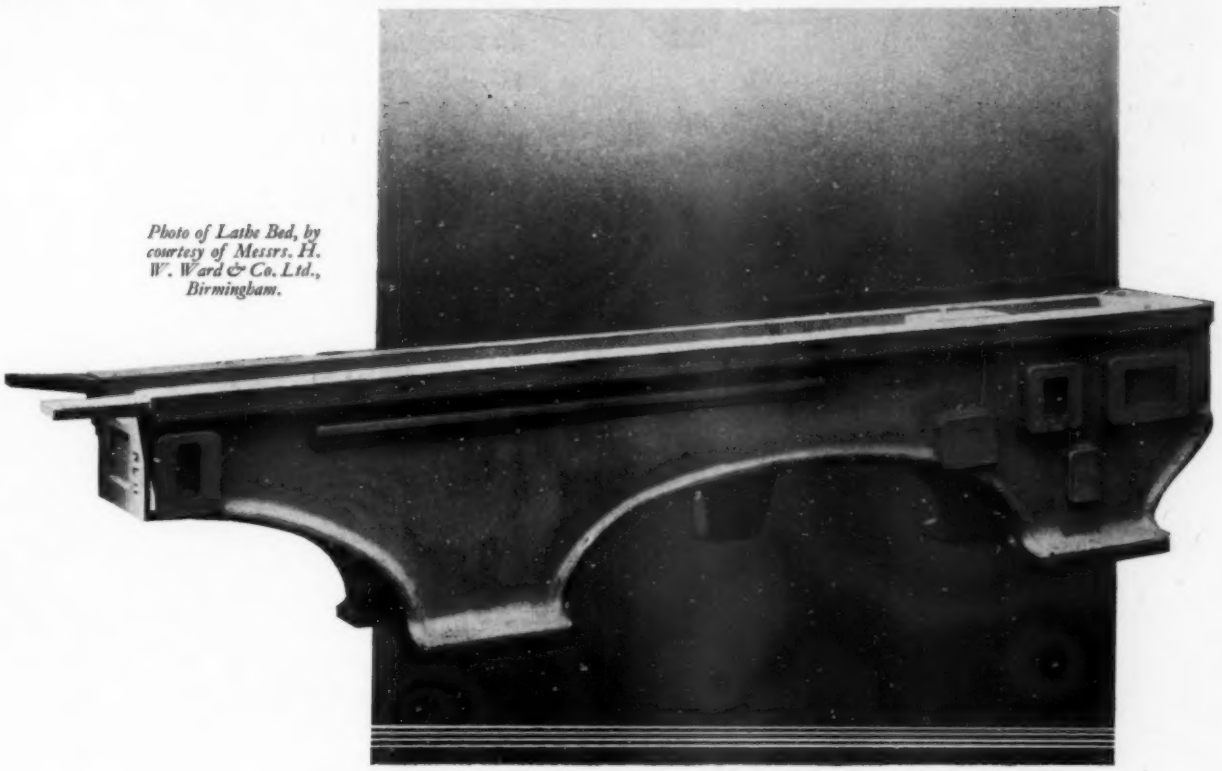

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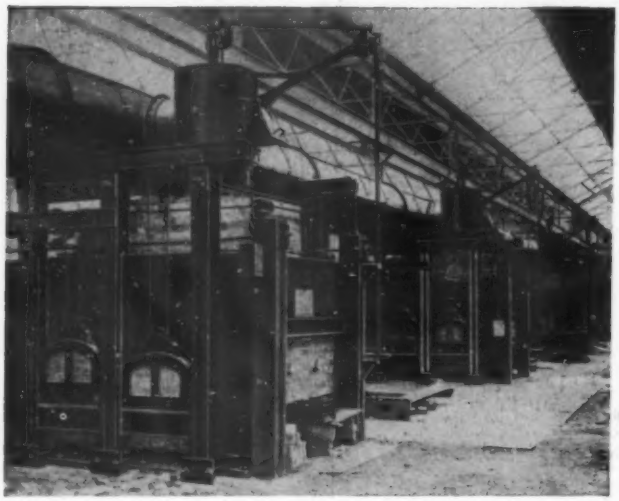

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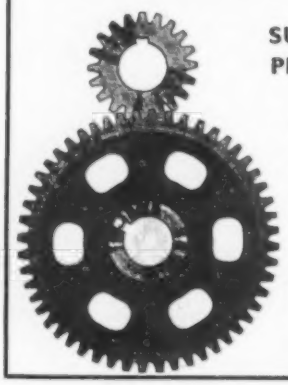

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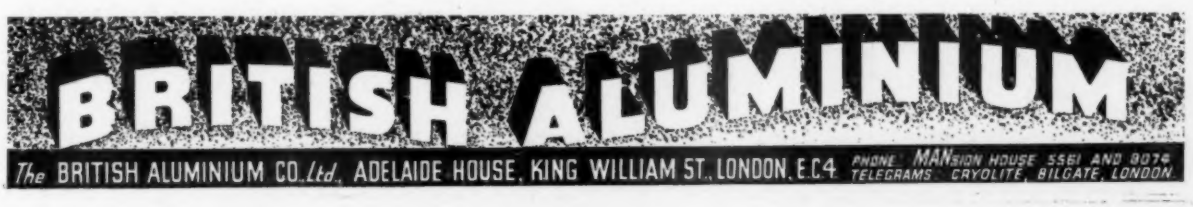
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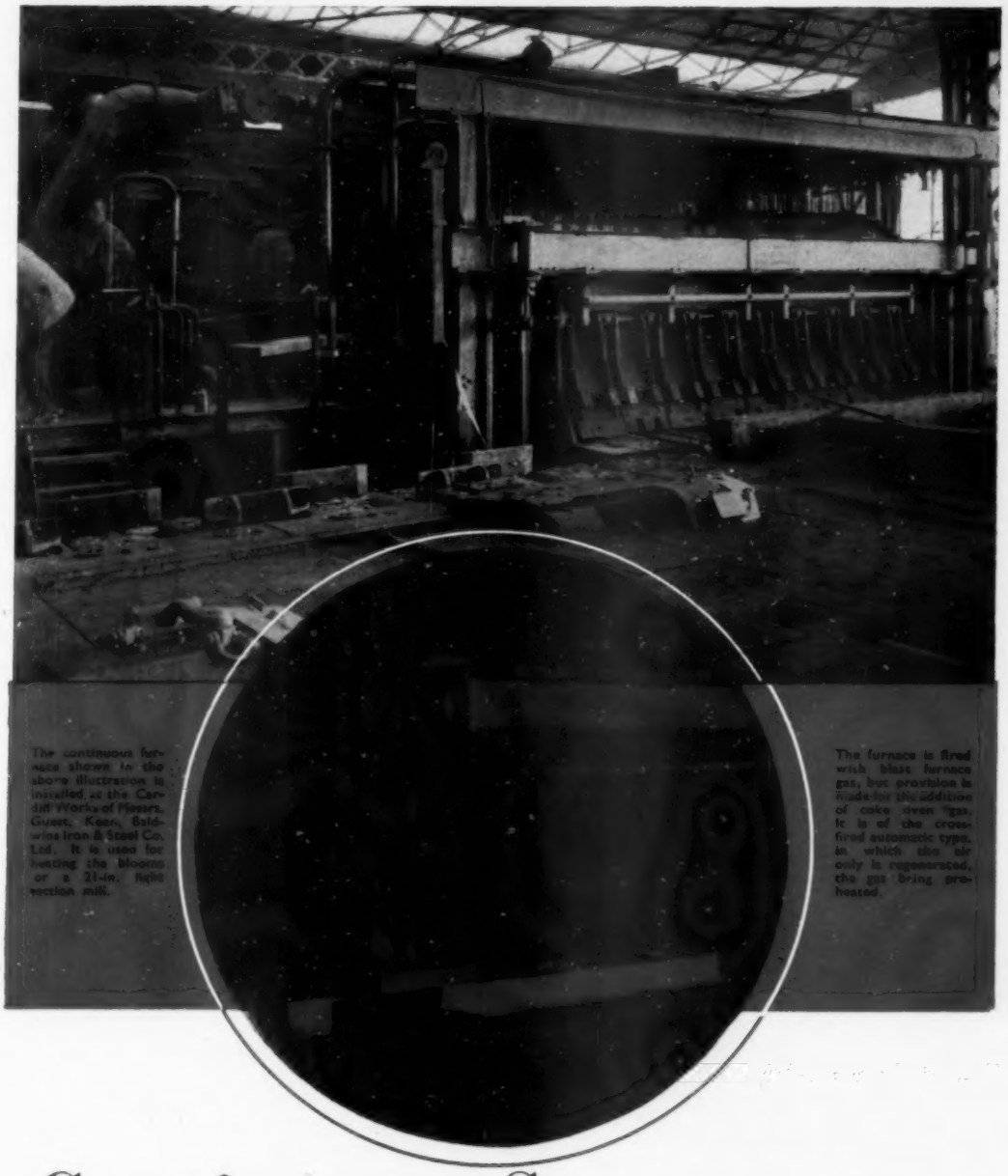

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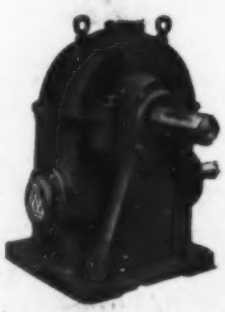
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